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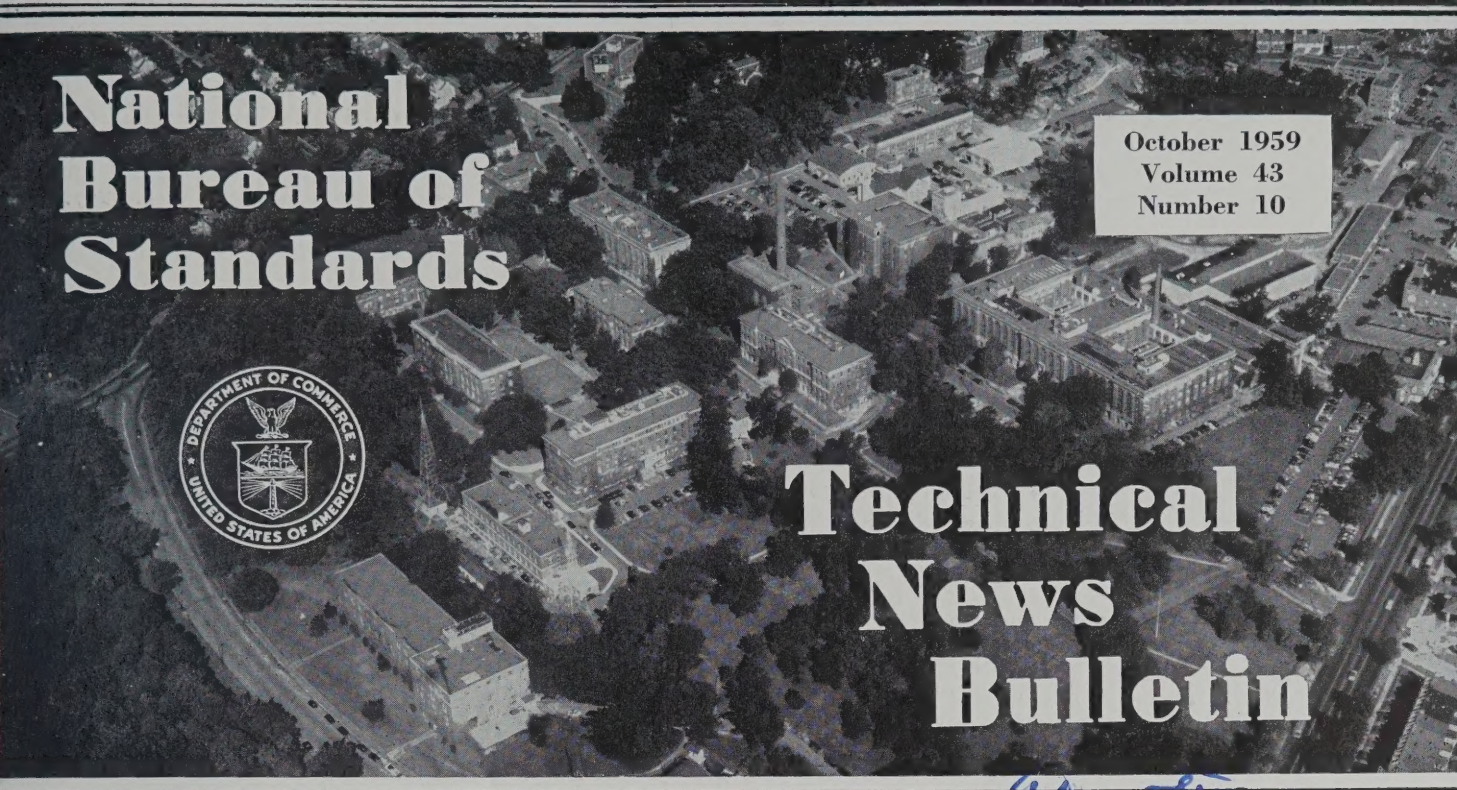

Technical News Bulletin

special issue

Recent Accomplishments in Data Processing

IN the field of automatic data-processing systems the National Bureau of Standards serves the Government as a central research and development agency and a readily available source of technical information. The scope of the program in data-processing applications and equipment design is illustrated in the development of methods for solving specific problems in both scientific and management areas, explorations of the potentialities of computers, logical design of computing systems, development of specialized circuitry, and evaluation of electronic components. This program was initially established to assist the Bureau and other government agencies in finding solutions for their data-processing problems and has grown with the electronic computer art to include a wide range of research and development activities. This special issue of the *Technical News Bulletin* reports a representative sampling of current work in the Bureau's data processing systems laboratories.

The Bureau's research laboratories, as well as laboratories in other government activities, have become increasingly aware of the time required to record and process experimental data before it reaches the high-speed computer that is used for final processing. Recent surveys at the Washington Laboratories have resulted in identification of dozens of projects in which this bottleneck can be removed through use of analog or digital techniques. How an analog machine, in particular, has been used to solve some of these problems is discussed on p. 188.

One result of the studies on circuitry has been the development of a series of flexible transistorized computer packages that can be combined to create specialized data recording and processing equipment for input to a large-scale digital data processor. These packages were the direct outcome of efforts to automatize some of the routine data handling associated with scientific experimentation in government laboratories. A description of these logical building blocks is given on page 184. The automatic data analyzer developed for the Weather Bureau, page 180, is an example of the way they can be interconnected to meet a specific data-logging requirement.

Concurrent with the work on problems of data recording has been the development of specialized computer programs for particularly difficult design problems. For example, one such novel program permits the designer of optical lenses to inspect visually on a display system a variety of previously computed focal plane images and to select the optimum. See page 191.

Another challenging research activity relates to the ever-increasing problem of information storage, search, and retrieval. This work has taken two forms: the development of an improved model of a microfilm rapid selecting device, based on a concept originally proposed by Vannevar Bush nearly a quarter century ago, and the development of special computer routines applicable to experimental machine search. Both the rapid selector and an initial experiment to test its operation are briefly described on page 178. A computer program, known

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as HAYSTAQ because of its similarity to the well-known simile concerning finding a needle, has been developed in cooperation with the Patent Office. With this program, a high-speed computer simulates certain features of the kind of search a patent examiner makes in analyzing a patent application, see page 192. Another computer program which simulates certain logical recall operations and which illustrates a limited degree of "machine learning" was developed and successfully demonstrated. The potentialities of this program, familiarly known as the IQ routine, are discussed on page 181.

Transistors and magnetic cores are increasingly being utilized in the development of improved computer circuitry. The transistor-magnetic core circuit, originally developed under a continuing Air Force project for improvement of computer components and circuitry, has been modified to provide a compact low-power pulse repeater of improved stability and increased logical gain. A small computer was built as a circuit test device. A detailed description of the development is on page 186.

Two other typical examples of special assistance to government agencies involved determination of data-processing procedures and equipment requirements. For the Veterans' Administration, data recording and processing equipment was actually developed and trial experiments conducted (p. 196). In the case of the Bureau of Aeronautics, the work resulted in recommendations of several optional data-processing systems for processing 30,000 hr of flight data annually (p. 194).

Other current data-processing activities, to be discussed in future reports, include research on using incidence matrix techniques for analysis of priority relationships in an intercommunicating network system, development of standardized packaged computer circuitry for assembling complex digital computing and control circuits, continued assistance in applying data-handling techniques to automatic mail-sorting operations, analysis of the feasibility of automatic data-editing and report generation, and feasibility studies to determine areas to which automatic data-processing techniques may be productively applied. This program is currently being carried on with the aid of SEAC, the Bureau's digital computer, and with an analog computer. Now under construction is the Pilot Data Processor,[1] a multipurpose computer network which is expected to be a powerful facility for augmenting the Bureau's data processing systems research program. Other aspects of the Bureau's program were discussed in the April 1958 issue of the *Technical News Bulletin.*

[1] Pilot Data Processor now under construction at NBS, *Tech. News Bul.* **43**, *38 (1959).*

THE RAPID SELECTOR

an automatic document retrieval device

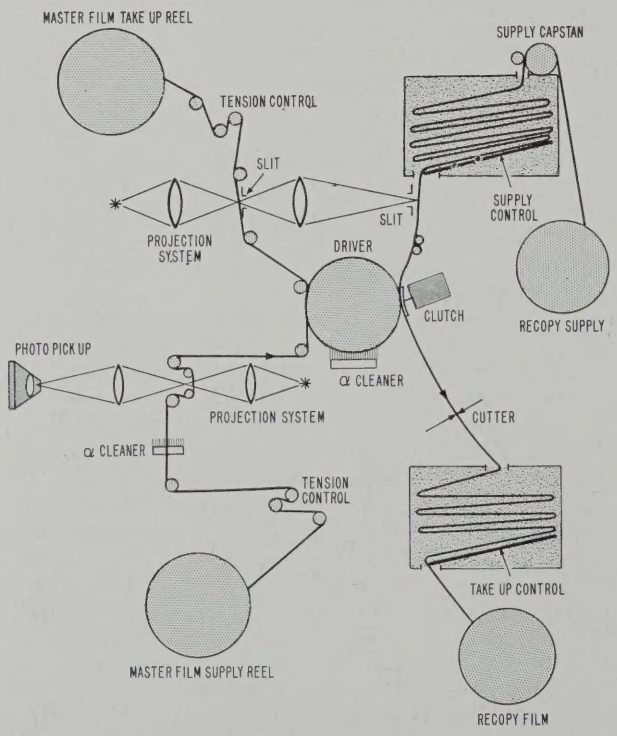


Diagram of film transport system for rapid selector.

THE Bureau has developed an improved model of an automatic document-retrieval device[1] for the Patent Office and the Navy Bureau of Ships. The machine rapidly retrieves information from massive files of correspondence, drawings, patents, or similar printed matter which have been recorded on 35-mm microfilm. Associated with each document image is a binary dot code which identifies the content of the document. The machine examines these codes rapidly—about 2,400 pages/min—and when a desired document is found, photographs it on a strip of recopy film. Development work on this rapid selector was carried out by T. C. Bagg of the data processing systems laboratory.

The rapid selector is an outgrowth of an idea originally proposed by Dr. Vannevar Bush more than 20 years ago. More recently, Yale University undertook the redesign of the machine to meet its own specialized requirements in document search. Subsequently, the Patent Office and the Bureau of Ships asked the National Bureau of Standards to study the machine to see how it could be further changed to meet their particular needs. For this program, the Bureau obtained a portion of the Yale equipment, modified the optical and mechanical systems, and redesigned the electronic circuitry using modern computing machine practice.

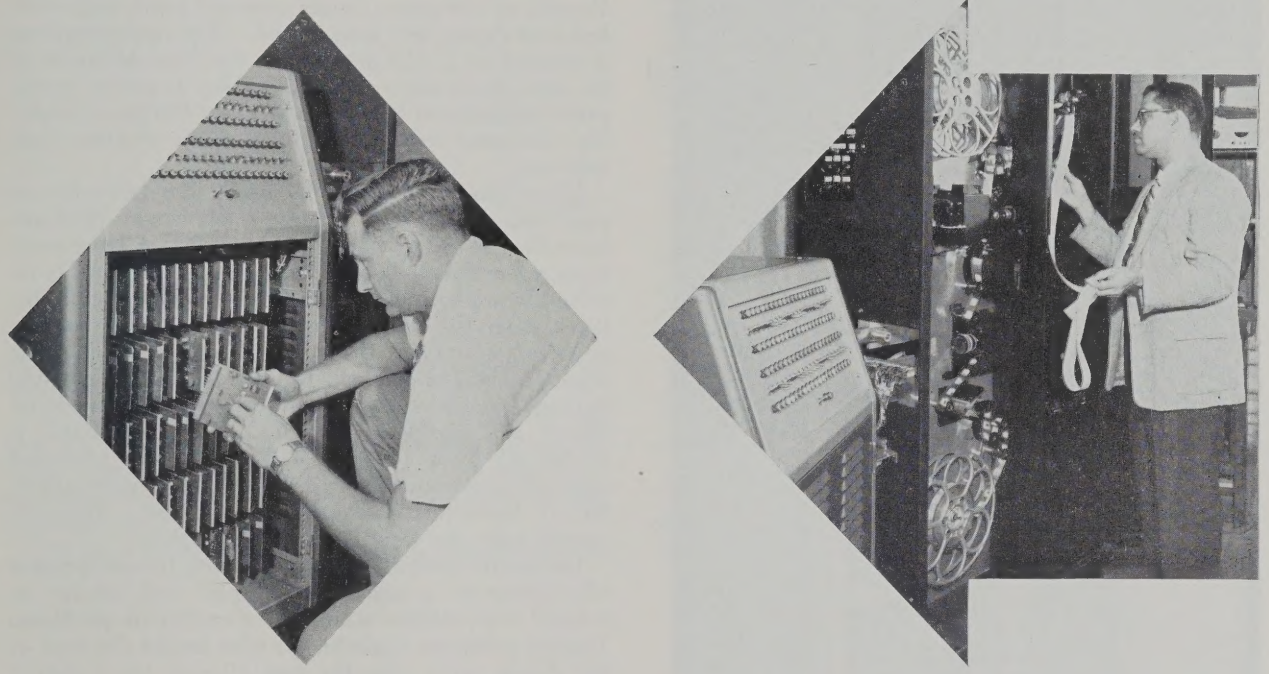
The machine identifies the required document by examining a binary dot code associated with each docu-

ment. A single code frame is about ¼ in. long and as wide as the film, and contains 6 rows of 46 bits each; 40 bits are for document information and 6 bits are for machine control. The mechanism that reads these rows of bits has sufficient tolerance to allow for normal dimensional changes in the film and slight skew in the rows.

As the film passes through the machine, its image is projected on a bank of photocells which scan the code. When a desired item is found, a high-speed clutch mechanism is activated. This clutch presses the recopy film to a drive drum, accelerating it to the same speed as the information or master film. By means of slit photography the desired item on the master film is registered on the recopy film. After the desired item passes the camera slit, the clutch is disengaged and the recopy film stops. As many consecutive items as desired can be copied without slowing or stopping the master film. The output of the machine is a recopy film on which are registered all the documents of interest.

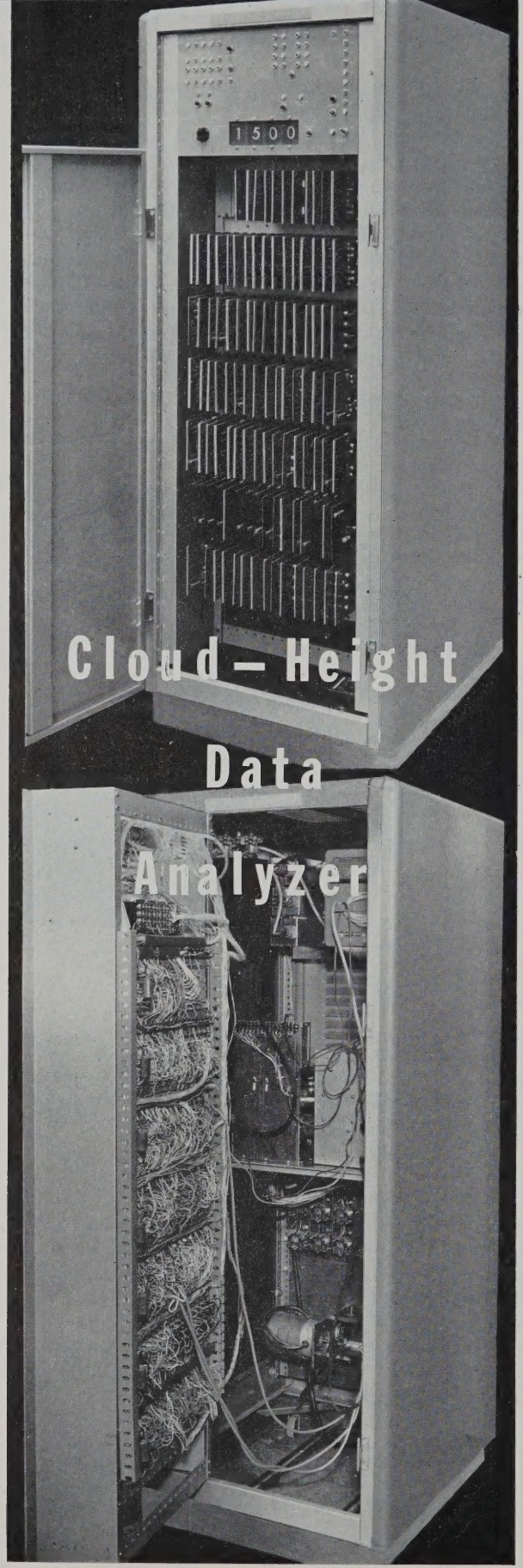
To test the operation of the rapid selector, a test film was prepared. It contains the contents of the NBS *Technical News Bulletin* for about a 10-yr period to show the wide variety of subject material that can be located with the selector. In all, more than 250 individual categories, simply or in combinations, were used in the index to describe the 900 articles. Successful searches on this test film have shown the practicality of the system.

The present selector is limited to using only one word per document. This word can represent many combinations of concepts. An improved electromechanical film transport combined with a multiword selector, now under construction, will perform much more rapid and sophisticated searches than the present machine. In the improved selector, signals caused by the recognition of the machine words can be combined using computer logic to give the printout command. A six machine-word code has been devised with which the Bureau of Ships is encoding a series of letters to be used in an encoding study. With this code system they will be able to find any letter or letters, written between certain dates, from a particular supplier about a specific type of equipment.



Right: **High-speed document-retrieval device. Document images are recorded on 35-mm film. Film transport (center) handles the film at the rate of 2,400 pages of documents per minute, makes copies of desired documents without slowing the film. O. R. Hall threads recopy film into the machine.** ***Left:*** **R. G. Pohlman replaces printed circuit board in packaged circuitry used with the rapid selector. A photocell scans the code on the film, sends a set of signals to this equipment. If the circuitry recognizes the signals as identifying a desired document, it activates the film recopying device.**

[1] *For further technical information, see* Status report on the rapid selector, *by P. F. Ordung and T. C. Bagg, Proceedings of the AIEE Summer Meeting, Montreal, Quebec, Canada, June 24–28, 1957 (CP57–862).*



Front view of the cloud-height data-analyzer cabinet showing printed circuit packages containing most of the electronic data-processing circuitry.

Cloud–Height Data Analyzer

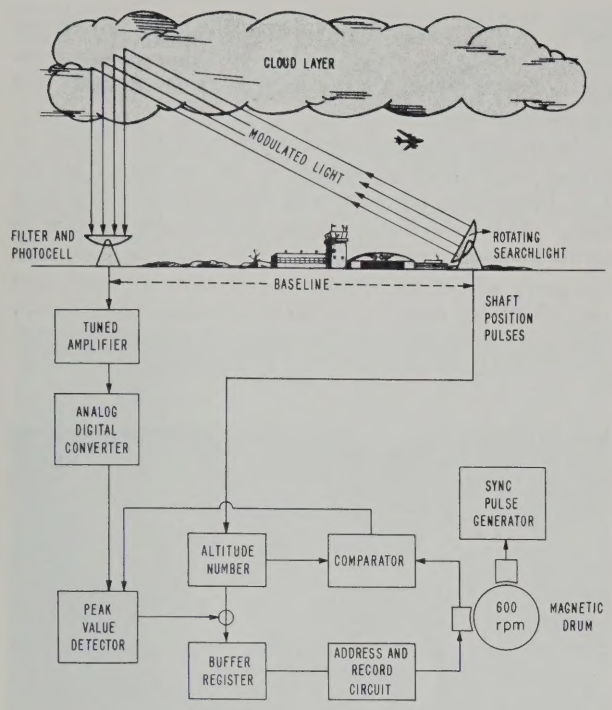
THE National Bureau of Standards has developed a special-purpose computer for the Weather Bureau to analyze data received from a ceilometer, or cloud-height indicator. On command, this small-scale data processor will tell an operator not only what the cloud height is at present but what the highest, lowest, or predominant cloud height was at any time in the last 10 min, or how often clouds occurred below some critical level during this same period. The instrument was developed by J. A. Cunningham and Paul Meissner of the data processing system laboratory as part of a program to assist and advise the Weather Bureau in applying computer techniques to automatic weather data analysis.

Cloud height is obtained by means of a device known as a ceilometer that can measure the height of clouds from the ground up to about 10,000 ft. A light beam from a searchlight is reflected by the clouds and is received by a photocell placed at a known horizontal distance from the searchlight. Either the light or the photocell is rotated through an angle of 90°. The cloud height is calculated by simple triangulation, using the angle at which the reflection from the cloud is received, and the known baseline. The light source is modulated by a rotating shutter, and the photocell operates in conjunction with a filter and a tuned amplifier to discriminate against ambient light. The ceilometer scans the cloud 10 times per minute.

Ceilometer indications are observed by an operator who interprets a cathode-ray display and obtains by manual computation answers to a variety of questions. Typical questions might be: At what height did most of the clouds occur over the past 10 min (or 1 min)? What was the lowest level at which a significant number of clouds occurred? The cloud height data analyzer automatically finds the answers to these questions, thereby relieving the operator for more important duties.

To do this, the cloud-height data-analyzer samples the ceilometer output and records the height at which the greatest signal is received during each scan. These data, which represent the most recent 10 min of information are stored in a small 100-word magnetic drum memory. After each scanning of the clouds there is a short period of time during which no information is being received; during this time the stored data are analyzed. The output of the equipment is a set of

Circuit packages mounted on a rack that swings out of the machine cabinet providing access to the package wiring for maintenance.



Inputs to the equipment consist of two signals. One is a shaft-position signal from the rotating searchlight; the other is an a-c signal from the photocell at the modulation frequency of the light source.

answers pertaining to the last 10 min, updated each scan.

The inputs to the equipment consist of two signals. One is a shaft-position signal from the rotating searchlight, consisting of a series of pulses. The other is an a-c signal from the photocell at the modulation frequency of the light source.

The shaft position pulses advance an altitude counter whose count is related to the angle of the searchlight. The angle is in turn related to cloud height, which may be as high as 10,000 ft.

The photocell signal is passed through an analog-to-digital converter which samples the signal in synchronism with the modulated light source. At the end of each scan, the equipment has determined the altitude number corresponding to the maximum cloud signal. This number is recorded on the magnetic drum memory in 1 of 100 spaces. The numbers from successive scans occupy consecutive spaces on the drum. The 101st number will replace the original number in space number 1, which was recorded 10 min earlier. Thus, the data are continually being updated.

Between scans, the data are summarized to determine which number occurs most often. At the end of this summation, an information storage unit contains the altitude which occurred most frequently over the past 10 min. Other questions can be answered by using counters and additional storage units to find the highest or lowest altitude at which the maximum cloud signal was observed three or more times.

The various outputs from the cloud height equipment are decoded to decimal numbers which are set up as switch contacts to control remote displays and teletype equipment.

Except for the output switches and magnetic drum, the equipment is entirely transistorized and was made almost exclusively digital in operation to assure a high degree of reliability.

A Computer Routine for Logical Recall

THE Bureau has developed a computer routine that simulates certain logical "remembering" operations. The routine was designed to illustrate some of the potentialities that high-speed electronic data-processing machines may have for automatic information retrieval, literature searching, or routing, classifying, and indexing of printed matter. This machine model of recall was devised by Mary Stevens of the data processing systems laboratory and has been successfully demonstrated on SEAC, the Bureau's computer.

Since the turn of the century the tremendous increase in all forms of technical literature has made ever more difficult the task of the scientist in finding material relevant to his field of interest. Only in the last few years has attention been given to mechanized means for rapid, thorough literature searching and information retrieval, although interest has now become widespread. The use of high-speed data-processing equipment appears to offer a promising way of searching and retrieving written matter with speed and consistency. As part of a general study of automatized information selection, the Bureau devised the present computer routine to explore the possibilities of pattern recognition at the level of a thesaurus lookup, limited machine learning, and simple verbal reasoning through verbal selection and recall operations.

The routine provides the investigator with a method for studying a number of aspects of the logical recall problem. First, the recall operations upon the information stored within the computer's memory represent a

special case of information selection and retrieval. Second, the machine routines provide easily understood illustrations of the potentialities the machine has in aiding certain auxiliary operations. These operations include machine reformulation of search questions in accordance with results already obtained, preliminary routing of incoming material to the appropriate geographic or subject matter location, and rudimentary machine indexing. Third, the routines include prototypes of machine operations that may have direct applicability in certain practical information selection situations. Fourth, the program is designed to simulate various steps in pattern formulation and recognition and to exhibit a limited degree of machine learning.

The program itself consists of an initial vocabulary of terms (nouns, adjectives, and proper names) that can be recorded in the machine's memory, together with clues to some of the logical and semantic relations between the terms. The program also includes routines for various operations upon the machine's store of "knowledge" as available at any one time.

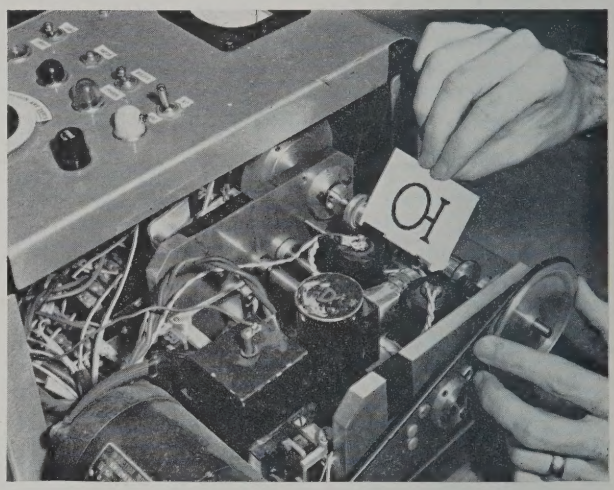
A small sample of such a vocabulary [1] is shown on the opposite page. It should be noted that the program is called "IQ," not because it demonstrates intelligence, but because it can provide correct answers to questions of a type sometimes encountered in intelligence tests.

As shown, the vocabulary terms are arranged alphabetically in one section of machine storage, and in a directly corresponding section are clues to other related terms. Thus the first word, "arsenic," is cross-referenced to the term found in storage cell 521, "rodent destroyer." Other cross-reference tag positions are left blank in the illustration—either because the machine model does not yet know about certain other relationships (e.g., arsenic to chemistry), or because the referral would be to terms not shown in this example. The present size of the actual vocabulary used with "IQ" is limited to 256 vocabulary terms, but the vocabulary is expected to grow and change in the course of future experimentation.

Communication with the machine can be by various input devices. The input means can include an automatic scanning device that "reads" a printed character which the program recognizes and, from a series of such characters, builds up a "word" that it then submits to a dictionary lookup operation.

The more usual method of using the IQ program for experiments in selective recall is by way of a teletypewriter, with which the operator inserts operational commands; the machine then prints out answers or program cues as required. The master IQ routine provides first for the identification of an input word, inserted by the operator, designating the type of elementary recall operation the machine is to perform and the selection of the appropriate subroutine to perform the assigned task. As necessary, additional program instructions for more complex operations are read in from magnetic wire or tape. When ready, the machine calls for input of one or more terms on which it is to operate. When these terms are received, the machine proceeds to carry out its assigned task.

As an example, suppose that the machine is given an initial vocabulary consisting of the names of all the U.S. Presidents, together with information about each man. This information might include the number of terms he had served, whether or not he was a general, his party affiliation, whether he is alive or dead, and any additional facts for which the machine has memory space.



Cyrillic character being mounted on a scanning device for information input to a computer. Information was processed in the machine to demonstrate a transliteration of Russian words into English equivalents.

Once the machine has this initial set of facts and a set of routines to carry out several operational commands, it is prepared to carry out a variety of recall operations as specified by the machine operator. If he asks the machine to "define" the term "Lincoln," the printout will contain all the other terms associated with Lincoln. If he asks to "Extend" the term "Whig Party," he will obtain a list of all the presidents who were Whigs. A "Locate" command will select from all the recorded facts associated with one man only those that have to do with geographic association, e.g., "Lincoln" with "Illinois."

More complicated types of command illustrate the type of question upon which the name "IQ" is based. To "Match" the terms "Washington, Jackson" (i.e., complete the series), we require the answer "Grant," because of the facts that "Washington" and "Jackson" have in common; that is, they belong to the subset of American presidents composed of Presidents-who-were-

also-generals. "Grant" shares the property of being dead, but "Eisenhower" is still alive. Similarly, in the "Reject" operation ("Which one of these does not belong?"), if "Eisenhower, Grant, Jackson, Lincoln, and Washington" are given, the IQ process will accept Eisenhower, Grant, Jackson, Washington, rejecting Lincoln because he was not a general. It will also provide the alternative solution of rejecting Eisenhower because he is alive and the others are dead.

SAMPLE IQ FILE

MEMORY CELL	CONTENTS	MEMORY CELL	CONTENTS
501	ARSENIC	601	21-00-00-00-00
502	BIRD	602	04-13-00-00-00
503	BURGLAR PROT.	603	00-00-00-00-00
504	CAGE	604	20-00-00-00-00
505	CANARY	605	02-04-19-00-00
506	CAT	606	15-18-19-21-00
507	DOC. No. 001	607	09-22-00-00-00
508	DOC. No. 002	608	06-09-00-00-00
509	DOG	609	03-10-15-18-19
510	DOGHOUSE	610	20-00-00-00-00
511	FISH	611	13-00-00-00-00
512	GUPPIES	612	11-19-00-00-00
513	LIVING THING	613	00-00-00-00-00
514	LOCK	614	03-16-00-00-00
515	MAMMAL	615	13-00-00-00-00
516	MECHANISM	616	00-00-00-00-00
517	MOUSETRAP	617	16-21-00-00-00
518	NUISANCE	618	00-00-00-00-00
519	PET	619	13-00-00-00-00
520	POSITION	620	00-00-00-00-00
521	ROD. DESTRYER	621	00-00-00-00-00
522	SALESMAN	622	15-18-00-00-00
523	TRUCK	623	16-18-00-00-00

Sample vocabulary which is part of "IQ" routine developed to explore certain logical recall operations that may be performed on a high-speed electronic computer.

These operations may be combined in various ways. In the "Select" operation, the operator may specify, for example, "Whig Party" and "two-term" as the selection criteria, and this request should result in a list of those Whig Presidents who served two terms. If, however, there are too few answers (or none at all), the operator may ask the program to make his question broader, e.g., all "Whigs" or all "two-termers." On the other hand, if there are too many answers, the question might be reformulated in more specific terms for any one or more of the original selection criteria, or the program might search for additional criteria that a number of the answers have in common. Thus it might produce a revised list of "Whigs-who-served-more-than-one-term-who-were-also-generals".

More complicated cross-reference systems can be generated as the questioning and directing of the machine program proceeds. For instance, the operator can ask the machine to develop files of facts common (or not common) to sets of Presidents, to show how these files can be interrelated, and to find the appropriate cross-references when given several input terms. The machine can also be given rules to suggest how the program can be most efficiently carried out. Moreover, the operator can give the machine additional facts at any time, with instructions to the machine to correlate these items with facts already in the memory.

In addition, provision is made for the machine program to accept from the operator or from other input means a hitherto unknown term occurring together with familiar terms which share one or more associations. The routine can provisionally assign to the new term the cross-references which the accompanying terms have in common, thus displaying a very limited degree of machine "learning." The machine handles these new facts on a trial-and-error basis, informing the operator of its tries as the program proceeds. The operator can tell the machine whether the tries are correct or not; the machine will "remember" only the "correct" relationships.

Obviously, the machine can operate only on those facts which are stored in its memory, and cannot invent new facts. However, it can, on command, generate complex sets of relationships between sets of facts that can be useful in indexing or finding data quickly. This machine process may seem to simulate human mental processes such as learning by association. However, the machine program does not attempt to follow the organizational patterns that may be utilized in the human memory. Instead, the objective is to explore efficient machine organization for operations that also happen to be performed by the human mind. By applying what is known about learning and recall operations to determining ways in which machines may be used to speed information selection and retrieval, it may become possible to free the documentalist or literature searcher for those tasks to which his creative, self-conscious, and critical intellect must be applied.

[1] *This sample is from an example suggested by S. M. Newman to illustrate the multiple possible categorizations of terms used in communication. He points out that a dog is sometimes considered as a mammal, along with cats, elephants, and men; sometimes as burglar protection; sometimes as a pet; and sometimes as a nuisance. See S. M. Newman,* Storage and retrieval of contents of technical literature—nonchemical information—second supplementary report. *Patent Office Research and Development Report No. 12, Washington, D. C. (November 17, 1958).*

For further technical information, see A machine model of recall, *by M. E. Stevens, Proceedings of International Conference on Information Processing, Paris, France, June 1959 (UNESCO/NS/ICIP/J.5.4).*

PACKAGED SWITCHING CIRCUITS

prepare data for computer input

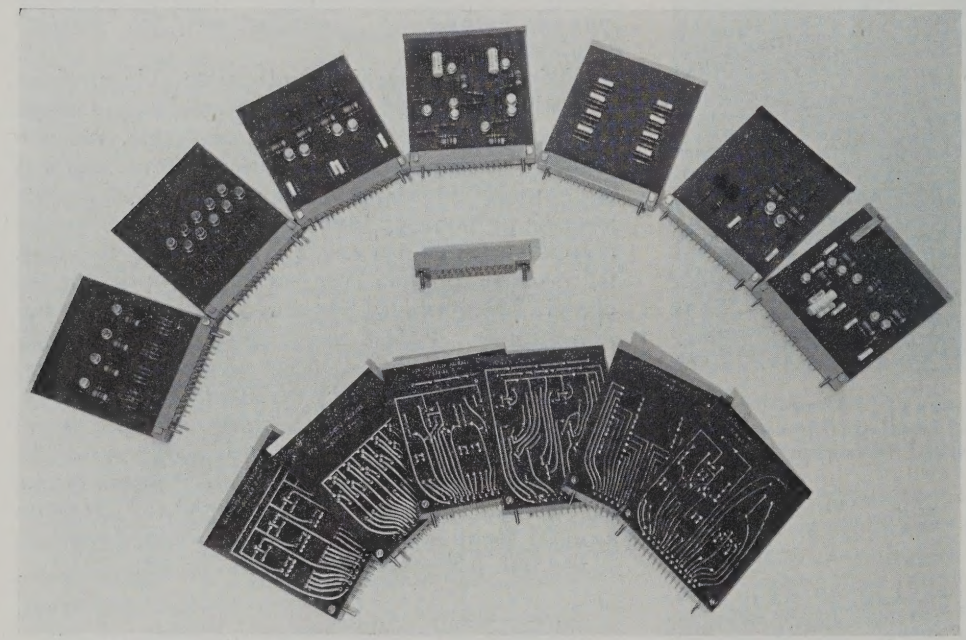
THE Bureau has developed a number of special-purpose transistorized computer packages that are expected to help automate many of the data recording and preliminary processing tasks encountered in its scientific operations. These versatile building blocks, designed by a group under the direction of J. A. Cunningham of the data processing systems laboratory, can be connected together systematically to accept raw data from experimental equipment and to transpose these data into a form suitable for input to a high-speed electronic computer.

Each assembly of packages can be tailored to fit the special requirements of the project, and can be used at the site of the experiment. The output from the system can be fed directly to a computer, recorded on a suitable medium for computer input at a later time, or used to drive display equipment that will keep the scientist informed of the progress of his experiment.

The accelerating pace of current scientific effort and the need for conserving technical manpower both emphasize the value of automatically recording and computing experimental data. Much human effort is spent in the simple repetitious tasks of taking data during an experiment and then performing large volumes of hand calculations. By automating the routine data-handling aspects of scientific experiments, savings of time and labor, as well as increased quantity and reliability of work output, can be realized both in basic exploratory research programs and in routine calibration and testing.

In surveying its own data-handling instrumentation problems, the Bureau decided that it could best meet its needs at this time with a series of flexible logical building blocks to record and perform preliminary processing of much of its data. These blocks can be used where: (1) Data are produced in large volumes; (2) data taking is extremely fast, extremely slow, or extremely precise; (3) a need exists to minimize human error, tedium, and eyestrain; or (4) computation is extensive.

So far, seven specialized major building blocks have been developed: A flip-flop, gating circuitry, a "one-shot" pulse generator, a logical OR-inverter, an indicator, an analog switch, and a power gate driver. They are, of course, compatible with each other and all operate at the same 50-kc pulse repetition rate.



Special-purpose computer packages developed to perform logical operations required for electronic data processing and recording tasks. Upper row, left to right: OR-inverter, indicator, flip-flop, power gate driver, gating circuitry, analog switch, and "one-shot" pulse generator. Lower row shows reverse sides of a number of packages.

Each package is constructed on a 4 in. by 5 in. plug-in printed board, and uses electronic components that are common stock items to avoid replacement problems. Most of the packages contain type 2N414 transistors, and some contain types 2N363 or 2N123 transistors. Power supply requirements are: (1) −12 v;

(2) +12 v; (3) a reference voltage for the analog switch; and (4) any other special voltages that drive external electromechanical devices. In most of the packages, some components or subassemblies are left unconnected, and must be wired externally to the package. Connecting these components externally allows greater flexibility in combining them.

Circuit Detail

The flip-flop package consists of 2 bistable flip-flop circuits and the necessary logical gating for converting each to one of several modes of operation. A normally open switch can be connected to the collector of either transistor to reset the flip-flop. In each package is also sufficient circuitry to construct 1 bit of a double-rank shift register or 2 bits of a serial shift register. The output of the package can drive 5 other flip-flops 5 OR-inverter circuits, 8 gate resistors, or 5 gate capacitors.

The gating package contains 8 logical gating circuits consisting of resistor-diode networks with capacitor inputs. They are mainly to supplement the gates in the flip-flop packages to complete the component requirements of shift registers, counters, or other systems. They can transfer information from a shift register or form feedback paths in various counting configurations. These gates can be driven by the output of a flip-flop, a "one-shot" pulse generator, an OR-inverter, or a power driver.

The pulse generator can deliver a single pulse whose duration is variable from 20 to 10,000 μsec. Regardless of the duration of the pulse, the circuit is prepared to generate a new pulse 20 μsec after the initiation of the first pulse.

The package consists of a flip-flop identical to the one in the flip-flop package, together with an integrator, a discriminator, and an amplifier. After the flip-flop is triggered, its output is integrated. When this integrated signal reaches a predetermined level, the discriminator is triggered. Its output is differentiated, amplified, and inverted, then differentiated again before being fed back to reset the flip-flop.

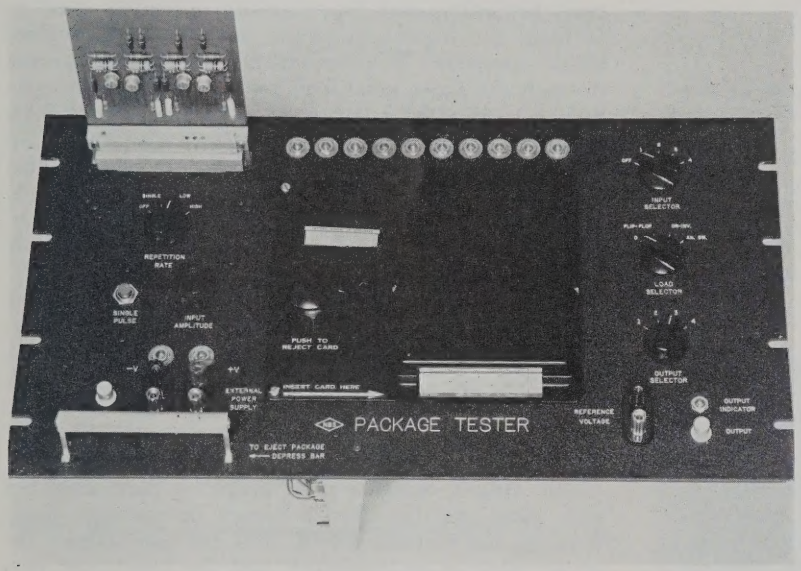
The output of the package, which can be either positive or negative, has the same driving capabilities as the flip-flop package.

Each of the OR-inverter packages, which can also be used as an AND-inverter, contains four separate 4-input inverter circuits. For negative input pulses, the 4-input diodes function as an OR-gate; for positive inputs, the diodes serve as an AND-gate. The output of the gate is amplified and inverted. One of these packages can drive 6 other similar packages, 6 flip-flops, 8 gate resistors, or 6 gate capacitors.

The indicator package contains circuitry for driving 10 incandescent lamps rated at 12 v, 18 ma each. This package can also drive electromechanical equipment within the power limits of its 2N363 transistors.

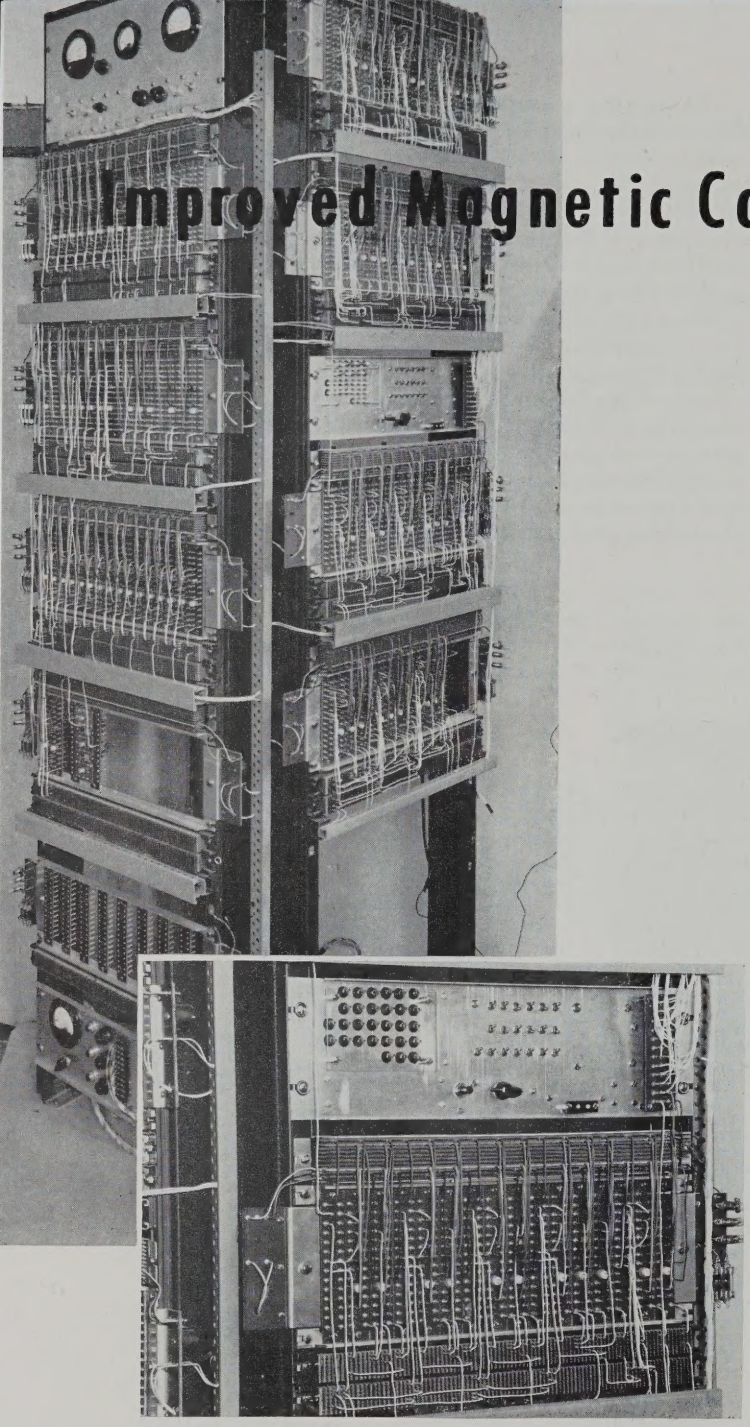
The analog switch package contains one flip-flop that controls an analog switch capable of switching up to plus or minus 10 v within 5 mv of the input. By proper selection of an output resistor, the switch will present an analog voltage corresponding to a specific input quantity or digit.

The power gate driver is designed to supplement the output driving capabilities of other packages. Where the output of a particular package may not have sufficient power to drive all the gates required by the system design, the gate driver—containing a number of amplifiers—can be added to drive as many as 40 other gates.



Instrument for testing special-purpose packages under simulated operating conditions. If a package does not operate properly, the tester gives an indication of the location of the faulty component. Internal connections in the tester are made with a punched card corresponding to the type of package to be inspected.

Improved Magnetic Core Digital Circuitry



Test computer using 81 magnetic cores built to demonstrate the operation of the circuit. It alternately adds 2 six-bit binary numbers and compares the sum with an inserted seven-bit check word. The operations are serial. Errors revealed in the COMPARE operation are counted by a three-stage binary counter which is also part of the computer. The addend, augend, and check-word are entered into the machine by means of toggle switches. A seven-place shift register using dynamic flip-flops serves as the machine's internal storage. The operations may be triggered externally or internally. Insert: Closeup of control panel.

CONTINUING RESEARCH on electronic computer circuitry and components, conducted for the U.S. Air Force Cambridge Research Center, has resulted in an improved digital magnetic amplifier. By modifying a magnetic core amplifier circuit developed earlier,[1] E. W. Hogue has designed a new circuit with improved stability, increased logical gain, and a faster complementer.

Semiconductor diode gating, because of its economy, flexibility, and dependability, is widely used to perform the logical functions of a high-speed electronic computer. To overcome the loss of signal power through the gates, amplifiers are inserted into the gating structure at intervals to regenerate the signal. Although vacuum tubes and transistors are commonly used to amplify the signal, saturable core reactors also show promise. The Bureau has therefore been investigating the use of these components as amplifiers because of their compactness, dependability, and low power consumption.

Essentially, these amplifiers consist of diode-resistor networks associated with miniature saturable-core reactors driven by a "clock." The "clock" in this case is a 300-kc low-impedance sinewave source. An amplifier serves to transmit pulses, corresponding to binary "ones," or no pulses "zeros" depending on the input to the stage.

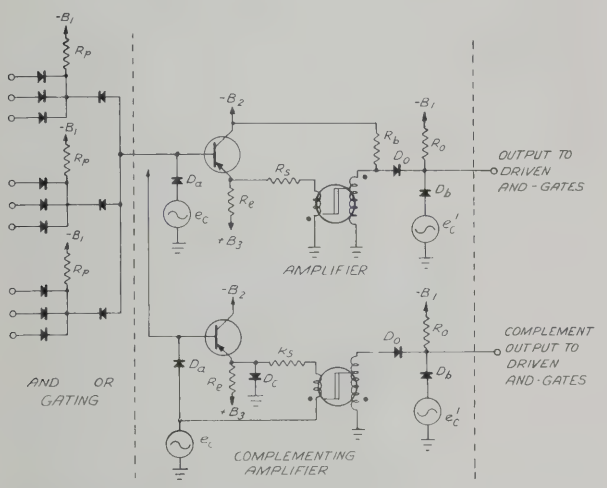
The circuit diagram of a magnetic core amplifier with associated circuitry is shown on opposite page. Between the vertical dotted lines are two stages; the upper stage is an amplifier, and the lower one is a complementer. Outside of the dotted lines are diode-resistor networks to provide the logical AND–OR gating. The stages can receive an input signal from the OR-gate.

Most of the power gain of the amplifier is provided by the saturable core reactors. Current from clock e_c', together with the total current from R_0 and all the resistors of the driven AND-gates in parallel, serve to return the reactor to the state of negative saturation during each half-cycle of e_c'. During the positive half-cycle, e_c' has no effect on the reactor because diode D_0 is back biased. The reactor, left to itself, remains negatively saturated once put in this state and presents such a low impedance to the driven AND-gates that they remain held at ground level during the negative half-cycle. Thus, binary zeros are transmitted.

If the AND-gates at the left of the diagram are not held at ground level during the negative half-cycle of e_c (which is opposite in phase to e_c'), a negative signal reaches the input winding of the reactor. Since this winding is in the opposite sense to

that of the output, the negative signal saturates the reactor in the positive state during the positive half-cycle of e_c'. Finally, during the ensuing negative half-cycle of e_c', the driven AND-gates return the reactor from positive to negative saturation. The reactor then presents a high impedance to the gates, so that they are not held at ground. The gates therefore transmit binary ones.

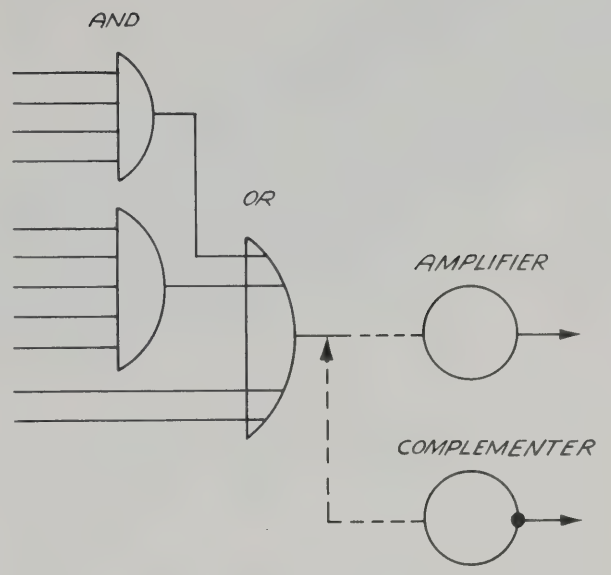
The transistor emitter follower, having nearly unity voltage gain, does not change the basic operation of the original circuit. However, it does improve the volt-second transfer function, and provides additional current gain. The current gain increases the logical gain of the stage and lowers the power expended in the interstage logical network. The improved volt-second transfer characteristic results from transistor base-charge storage which in turn results from driving the



Circuit diagram of transistorized magnetic core circuitry.

transistor into saturation at the peak of the pulse signal. Then, even though the pulse arriving at the OR-gate input may terminate very soon after the peak, the transistor base is not pulled down to ground potential at this instant because of the OR-diode opens and the clock voltage holds up long enough to result in a full pulse at the emitter terminal. However, no storage and no reshaping take place if the signal fails to reach the value of the collector supply as in the case of no input pulse. To be sure that no false pulse gets through, current through the core secondary biases the core toward its "unset" state.

The complementer differs only slightly from the amplifier. The diode D_c and the base resistor R_e provide a current-limited low-impedance clamp to ground at the emitter. If a pulse is not transmitted by the emitter follower, the clock voltage applied to the core continually causes the core to receive and transmit

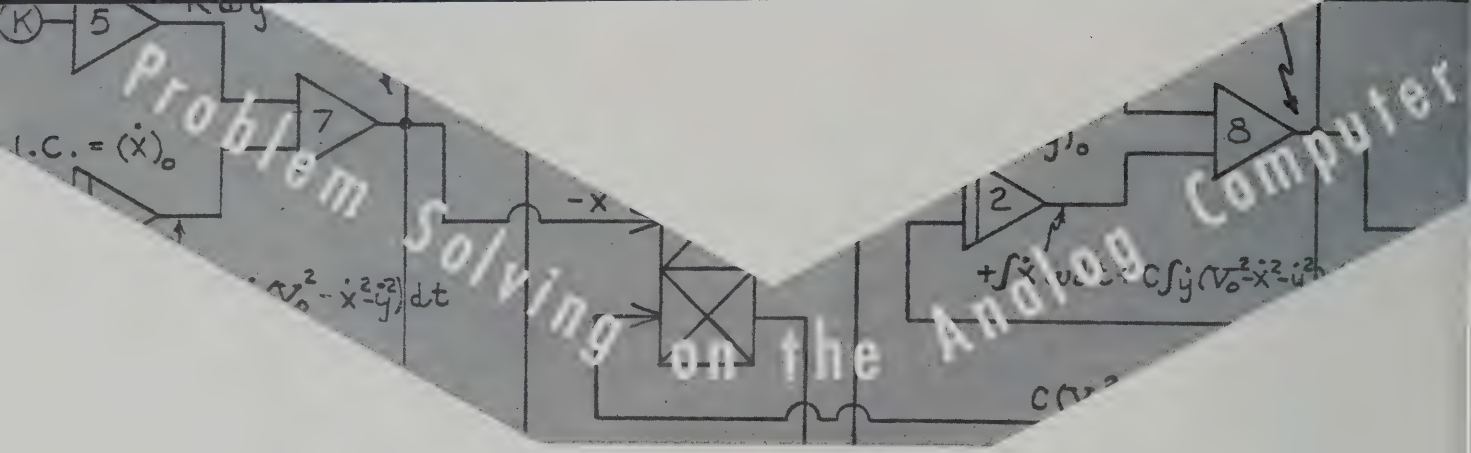


Symbolic diagram showing the logical possibilities of the magnetic core circuit. In the circuits actually constructed, up to four OR-inputs and five AND-inputs were used. The logical driving power of the amplifier and complementer was around 30 each. Several hundred picofarads of lead capacitance could also be driven in addition to the load. The clock frequency was 300 kc, and its amplitude was 7 v rms.

pulses because the core magnetizing current is not large enough to open the clamping diode. But when a pulse is transmitted by the emitter follower, the diode opens, and the clock voltage impressed on the core directly is opposed by the pulse appearing at the emitter. The core therefore is left in the unset or no-pulse state and transmits nothing during the next half-cycle. This complementer inserts only ½-cycle delay; the complementer of the original circuit inserted a full cycle of delay.

The final improvement in the previous circuit is the output AND-gate consisting of a pullup resistor R_0 and two diodes, D_0 and D_b. The value of the resistor is adjusted to provide sufficient current to drive all the ground capacitance of the connecting leads—up to several hundred mmf—which run from the amplifier or complementer to all the gates driven by them. As a result, the current carried by a driven gate never need be greater than is required by the core directly associated with it. A single stage can drive as many as 30 other stages. The total power input to an amplifier or a complementer is around 0.5 w and the power per singly loaded AND-gate is 0.15 w. Clockpower per core is approximately 50 mw.

[1] Magnetic amplifier for digital computers, *NBS Tech. News Bul.* **42**, 77 (*April 1958*).



THE Bureau maintains an electronic differential analyzer—more commonly called an analog computer—for the solution of problems that arise in connection with its scientific program. This machine has proven to be a valuable research tool because of: (1) Its ability to accept and produce information in the form of continuous plots; (2) the rapidity with which setup and parameter changes can be made; and (3) the clear picture of the physical relationships that it presents. It permits engineers and scientists to simulate complex equations or physical problems and save many hours of calculation or experimentation, thus freeing the individual to pursue more rewarding tasks.

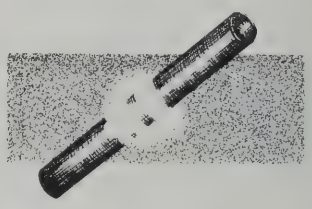
In scientific research, new problems not previously apparent, contemplated, or easily solvable frequently arise. The solution of one problem reveals the existence of other more difficult problems whose solutions require the development of sophisticated computation techniques and specialized mechanical aids. The analog computer, with its wide variety of built-in computational capabilities, has shown itself to be a powerful and essential aid in furthering scientific research.

The machine is particularly suitable for handling dynamics problems and the linear or nonlinear differential equations of lumped-parameter systems in one independent variable. It can also be used for curve-fitting and for analyzing a variety of transcendental, trigonometric, algebraic, and partial differential relations. Very large or very small numbers can be scaled; answers can be obtained to two and sometimes three significant figures.

The analog computer is also useful to the scientist who wants to simulate quickly some of the processes that may occur in an elaborate experiment without performing the experiment itself. By analyzing the results obtained with the computer, he can change variables in the simulated experiment to improve his design and save the time that might otherwise be lost in fruitless preliminary trials in the laboratory.

The problems worked on the analog computer illustrate the wide variety of mathematical and physical processes that the machine can simulate, analyze, or evaluate. For example, analysis of a zone-melting operation required setting up a mathematical model of the physical process and then solving the equations on the machine. The results indicated the optimum heating conditions for a particular metal sample. In another case, the machine performed a Fourier analysis of some waveforms produced by an electronic oscillator; the results enabled the experimenter to select among a set of components the best to suit his needs. As a further example, the machine manipulated a function of two independent variables to produce a set of contours corresponding to that function—and then drew the contours on an X–Y plotter. These and other problems, representative of those solved, are discussed further below.

Simulation of Zone Melting



Zone melting is a practical method for preparing extremely pure metals in small amounts. The Bureau, as part of its standard samples program, is investigating this technique to produce ultra-pure tungsten.

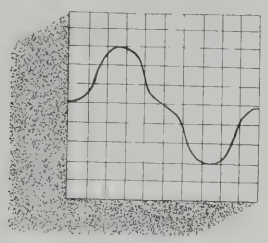
Since even partially purified tungsten is very expensive, knowing how the material will behave during the zone-refining process is desirable before trying experiments. It was not known with certainty whether the melting at the narrow heated surface of a tungsten rod would proceed axially or vertically, or whether the molten portion would adhere or drip off. These conditions are influenced by heating rate, rod diameter, thermal conductivity, emissivity, latent heat of fusion, and surface tension.

Heat flows radially inward and axially up and down by conduction; it also flows radially outward by radiation, at a rate measured by the Stefan-Boltzmann fourth-power law. When the melting point is reached at any specific location, the temperature rise halts briefly while the latent heat of fusion is absorbed, and then continues at a slightly different rate.

The machine must consider the relations between all of these numerous variables. All of the variables can be assigned numerical values, and the values can be inserted into the machine. The course of a typical melt can then be followed on the time-versus-temper-

ature curves drawn by the computer. With all parameters fixed except for the heat input, trial runs were made for different heat input values until one was found that gave a satisfactory time-of-melt for the proper shape of melting zone. The procedure was repeated for five rod sizes whose dimensions were read in by a simple resetting of the dials on the computer.

Fourier Analysis

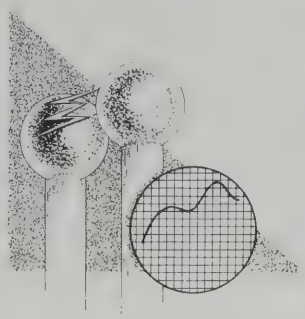


The Bureau's electronic laboratories designed a crystal-controlled oscillator to have a stable output rich in harmonics. Any individual harmonic can be selected from the output with an L–C filter of appropriate design. In developing the oscillator, it was necessary to know the amplitude and frequency of the principal harmonic components to be sure that the circuit would have a useful output signal. Commercial wave analyzers will provide this information, but only for lower frequencies. At the higher frequencies generated by this oscillator, only a Fourier analysis of the recorded waveform is possible.

Selecting a crystal for the most desirable and useful harmonic output is a trial-and-error procedure. Twelve different crystals were tried, and the waveform generated by each was recorded from an oscilloscope. To avoid the tedious and not-too-accurate method of hand analysis, the curves were analyzed by the analog computer to provide a basis for selecting those crystals serving best the needs of the equipment designer.

Fine copper wire, held in place by gummed tape, was laid out in the form of one such curve on the table of an X–Y function generator. As the x-coordinate was swept by an analog voltage, an rf head followed the wire to determine the y-voltage. Using the values for y, the computer generated sine and cosine functions from the equation $y = -\omega^2 y$, and integrated the products to find a numerical value for one Fourier coefficient. When two voltage dividers were reset to provide a different value of ω, the procedure was repeated. The procedure continued until the machine had obtained 10 coefficients. Each curve was analyzed similarly.

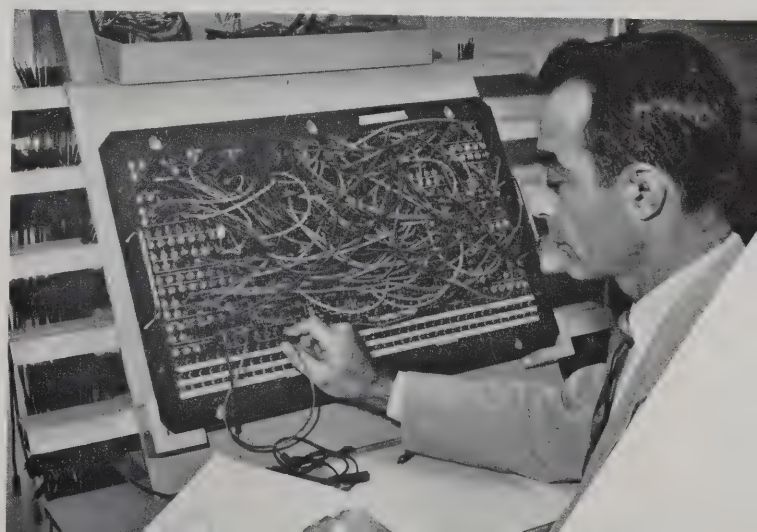
Simulating Surge-Voltage Dividers



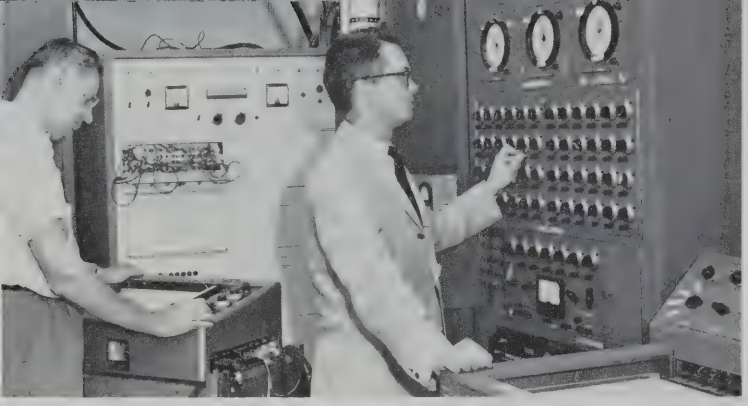
Most electrical insulating materials can withstand, for very short intervals, a somewhat higher voltage than is sufficient to produce electrical breakdown or flashover on a continuously applied voltage. Because the effect is large enough to represent some additional protection in the case of direct lighting strikes, it is important to make reliable laboratory measurements of electrical breakdown values of steeply rising voltages. Measurement of voltage values for such surges can be obtained by using surge resistor units in voltage dividers. The dividers step the voltage down to levels that can be read on conventional instruments. However, results of such measurements have been in doubt because the behavior of the divider has not been accurately determined.

The high-voltage laboratory has been investigating for the American Standards Association methods for specifying the accuracy of these surge-voltage dividers. A surge voltage does not rise instantaneously to a fixed value, nor does the divider take a continuously precise fraction of the voltage. However, these imperfections can be expressed analytically.

From appropriate input data, the analog computer calculated and plotted the waveforms corresponding to the response of the divider circuit either to an instantaneous step voltage or to an assumed shape for the surge voltage. The results have provided a determination, more accurate than previously possible, on the behavior of these dividers for measuring steep wave fronts.

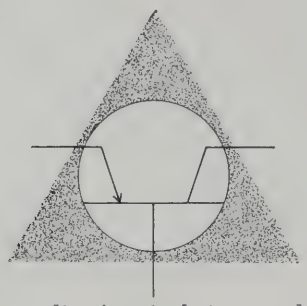


J. P. Nigro wires patch board for problem to be run on the analog computer. The machine permits scientists and engineers to simulate complex equations or physical problems and save many hours of calculation or experimentation.



Analog computer maintained as a research tool to assist in the Bureau's scientific program. Standing at the *X–Y* function generator and plotter at left is T. L. Childs. At right is E. S. Sherrard.

Analysis of Transistor Operation

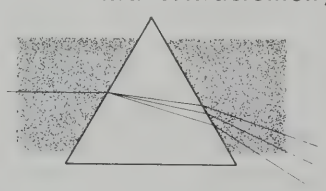


Increasing application is being made of complex computing and control circuitry for airborne and field use. This equipment requires electronic components of unusually high reliability to withstand possibly extreme environmental conditions. The transistor is one component whose properties and applications are under intensive investigation for such use.

Digital or pulse circuitry makes its own special demands on the transistor. Optimizing the design of the transistorized switching circuits that are employed in digital equipment makes it necessary to describe the physical transistor in a form consistent with the concepts of the circuit engineer. Therefore, the Bureau derived an equivalent circuit representation of the transistor specifically for the nonlinear operation encountered in the large-signal switching circuits. It differs from previous circuits primarily by representing the input impedance as well as the transfer ratio even in the condition of saturation.

The equivalent circuit was readily simulated on the analog computer for several modes of operation. Each simulation produced waveforms and amplitude responses that were in close agreement with limited experimental trials. The results provide a characterization of the transistor so that its performance in a switching circuit can be accurately predicted.

Fundamental Refractometry



Highly accurate values of the refractive index and dispersion for transparent media over a wide spectral range are essential to the optimum design of optical systems for measurement, detection, analysis, and photoreproduction. These values also fill a need in establishing a number of the physical constants used in all branches of physics, chemistry, and engineering. For example, in liquids, the refractive index is often used as a measure of the purity and density of solute in solution.

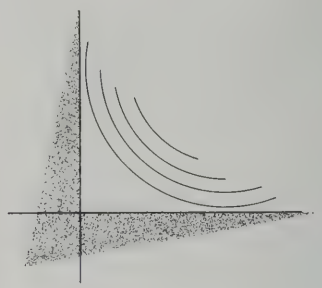
As part of a study of the optical properties of materials, a mathematical model was derived, based on harmonic oscillation analysis, to describe the variation of refractive index with the frequency of the incident radiation. The derivation led to the relation $y=c\lambda^2/(\lambda^2-b^2)$, where y is the refractive index, λ is the wavelength, and c and b are constants.

Prior to the machine computation, the above equation was differentiated and was then set up on the analog computer in the form

$$\frac{dy}{dt}=-\frac{2ay}{c}(y-c).$$

The constants were altered systematically until values were found that gave dispersion curves over a wavelength range of 3 to 50 μ fitting certain experimental data.

Contour Tracing



Occasionally purely mathematical functions are investigated on the computer to devise new techniques and to increase competence in solving technical problems. For example, a method for contour tracing was investigated. In this type of problem, a function z of two time-dependent variables, x and y, is solved to generate contours of constant z in the x–y plane, eliminating time as an explicit variable. If the function were $z=|x|+|y|$, then the contour would be a square tilted 45°.

The analog computer was set up to develop such contours on an X–Y plotter in a simple, straightforward manner. Experimental curves were run for several different functions; they showed undamped oscillations—as expected—about the desired contour. Special circuits were then devised to provide sufficient damping for accurate contour tracking.

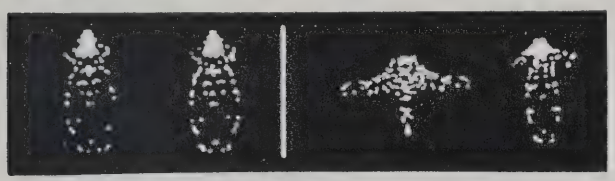
Studies are currently underway to extend this method to other functions, and to apply it to data taken from physical experiments.

LENSTAR

AIDS LENS DESIGN

THE BUREAU has developed a computer routine to assist in the design of optical lenses. Essentially it provides a visual presentation of any one of several previously computed focal plane images and a rapid method for interpolating between them so that the operator may choose the image that looks best to him. The program, called LENSTAR, was developed by D. C. Friedman of the data processing systems laboratory.

Skew-ray tracing through lenses is a long, laborious process when carried out by hand, and is a problem particularly well adapted to solution by a high-speed electronic computer. Usually the solution requires several major computation steps, including preliminary studies to indicate which paths will be most fruitful in the final computation.



Representation of focal plane images as seen on an oscilloscope screen. These images were computed automatically by LENSTAR. The distances from the lens to the focal plane can be altered in small increments by pushing a button on the computer control panel. The first two images represent the initial data for the first computed plane; the third image is near best focus, but is too close to lens; the fourth shows the plane of best focus.

The LENSTAR routine was developed to locate the plane of best focus for a lens after the initial part of the problem has been run on a computer. The computer traces rays through a lens to produce sets of punched cards giving the coordinates of the rays at six chosen planes behind the lens. These reference planes are selected to bracket the expected plane of best focus. At this stage, the LENSTAR program can help determine the location of the optimum image plane, which may lie somewhere between two computed reference planes.

Choice of the optimum plane is usually a matter of human judgment, since no lens can produce a "perfect" image. However, LENSTAR makes it possible for the lens designer to select what seems to him the "best" of several images after actual visual comparison.

LENSTAR takes the computed data for any two adjacent reference planes as initial data. It can handle up to 127 rays and their reflected images at a time. From the data for the two planes, numbers are generated for each ray to indicate its path through space. The data for the first plane are then displayed upon the face of a cathode ray tube. Because the display system can show only 96 points at one time, the data are cycled through the display equipment and the persistence of the phosphor helps give the viewer the whole picture of the ray figure.

The operator may examine the display as long as he wishes and then, by pushing a button, cause the computer to produce the display for another reference plane. This process may be repeated as often as desired. The time for the computer to produce either image is of the order of one second.

However, the operator may not like the way things are proceeding. The focus may have been passed, or the step size between image planes may be wrong. In this case, he presses a button which asks the machine to print out the location of the last plane, and then instructs it to modify the process. Several modifications are possible by typing the appropriate word on the machine's input typewriter as follows:

STEPIT will cause the computer to ask for a change in the incremental rate of the image plane. The new increment may be 8, 4, 2, 1, ½, ¼, or ⅛ times the spacing between the two initial data planes. If a negative number is entered, the plane will move toward the lens; if positive, away from it.

RESET will cause the computer to start at the original data plane again.

REDATA will cause the computer to ask for new data and start from the very beginning of the program.

SCALE will cause the computer to ask for a new image scale and new image centerpoint. The scale, like the step, may be varied in binary fashion between 8 and ⅛ of the basic scale. Any point on the screen may be chosen as the center of the new display.

SNAPIT will cause the points of the last image to be presented once, and then make the screen blank out. This permits taking a picture of the screen with each point at equal brightness.

This program is sufficient to show the possibilities of this kind of data processing and to suggest additional features. For example, it is possible to include a subroutine that would always center the display at the center of gravity of the image. Another subroutine might then, according to criteria yet to be determined, decide whether the focus is better or worse than that at the last image plane, and cause the plane to move to the best focus, at which time a photograph would be taken automatically and pertinent data concerning the location of the image would be recorded.

One of the problems to be overcome is that as many as 1,000 points might be desired for a single image. One method proposed for solving this is to store the image data on tape, then display it on a storage tube, which would present to the operator all spots at equal brightness. He could then cause erasure or take pictures at will.

A Program for Automatic Searching of Chemical Literature

THE Bureau and the Patent Office have been cooperatively studying the technical aspects of patent searching to find methods for mechanizing as much as possible the search process. One of the major tasks in the cooperation effort has been to develop a program for automatic searching of patents by making use of an electronic computer. This program, known as HAYSTAQ, has resulted in an experimental system designed for the storage, search, and retrieval of technical literature, particularly in the field of chemistry. The studies are being carried out by Ethel Marden of the data processing systems laboratory and H. R. Koller and H. Pfeffer of the Patent Office. Although systems of the HAYSTAQ type will not eliminate completely the manual literature search required of a patent examiner, they may be expected to reduce such search to relatively few documents.

The HAYSTAQ system simulates on an electronic computer certain features of the manual search which a patent examiner now makes; this system has been programed for SEAC, the Bureau's high-speed computer. Although the investigation so far has been concerned with the literature of chemistry, an attempt has been made to develop principles broad enough to include other scientific categories. The system consists essentially of four parts: (1) A data-assembly and data-checking routine for the complete disclosure file of information to be searched; (2) a data preparation routine for the question to be asked of the file; (3) the search routine itself, with all of its included subroutines; and (4) the "checkout" routine, which evaluates the apparent answers found to questions. At the present time, the system requires that a technically trained person read and analyze each document, and that he designate the portions to be coded for the automatic search.

Top: **Ethel Marden at the control console of SEAC, the Bureau's high-speed electronic computer, where some of the experimental work on HAYSTAQ was performed.**

Ordering of Information in a Disclosure

Before a patent application is coded for searching, it must be inspected closely to determine how much and what kinds of information it contains, and to evaluate the relative importance of the various pieces of information. The information in a disclosure on chemistry is arranged in a hierarchy of relationships. The largest segment treated is a complete chemical process with all of its disclosed steps. The next largest segment is a composition or admixture. Each composition is subdivided into groups of ingredients, with groups represented by numerical codes. The individual units within such a group are called descriptors, and may represent such items as individual atoms or bonds or substructures containing a number of different kinds of atoms. Superimposed upon this hierarchy is provision for recognizing such other relationships as alternativeness, equivalence, absence, and negativeness.

The search procedure is essentially a "matching" process on all levels to find like components. Provision is also made for recognition of a smaller configuration included in a larger one. The inclusion of such concepts results in a multiplicity of mutually exclusive search paths, and permits a great variation in the kinds of searches to be made. At all levels of the hierarchy, there is an effort to screen out as soon as possible those documents that will not provide an answer. The screens used are themselves ordered as to their probable effectiveness. In all of the data, for both question and disclosure, the descriptors are arranged in an ordered sequence to make it easier to terminate unprofitable searches.

Typical of the questions which were asked in the first generalized pilot program is the following:

> "Find a disclosure of a nonaqueous composition, for use against fever and ague, comprising boneset; an alkylated cyclohexenyl hydrocarbon containing at least 7 carbon atoms and 1 double bond; an acyclic ketone consisting of 11 carbon atoms, 1 oxygen atom and 1 double bond; a member of the group consisting of quinine and cinchonidine; and as a flavoring agent, an extract of the family pinaceae containing an alkylated cyclohexenyl alcohol containing at least one hydrogen atom, 1 oxygen atom, 10 carbon atoms, and 1 double bond."

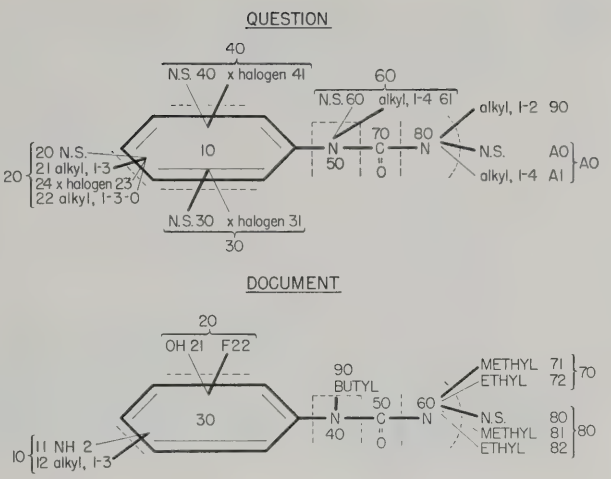
Search Routine

The search routine is in one sense a monitor or supervisory routine, which selects a search path after looking into the nature of the question being asked and the characteristics of the document being searched. This routine is a kind of assembly program for the required subroutines, where some of the subroutines are greater than the entire search routine itself.

Test runs of the general program revealed certain inadequacies in the description of chemical compounds; therefore a very large detailed program for tracing the topology of functional groupings of structures within the compound was planned and executed. This subroutine takes into account many of the difficulties presented by the peculiar technical aspects of patent searching.

Included in this topological tracing subroutine are several relatively sophisticated concepts. Of great concern to a patent examiner is the need to ask a search question generically. Two provisions for doing this are incorporated in the topological tracing subroutine: one makes it possible to ask for a genus and to accept as an answer any specific member of the genus; the other takes into account the problem of the structural "Markush group." By "Markush group" is meant a synthetic genus whose scope is determined by listing all of its members. That is, a single structural entity may define an entire class of compounds by showing a fixed nucleus with various alternate constituents listed at particular points in its topological diagram. It is possible to specify for a Markush group that in addition to acceptance of any one of the listed members of the group, the program will be satisfied with "no substituent" for that connection.

To carry out the tracing, a basic vocabulary was devised of functional groups within the whole chemical structure; the data to be handled consist of a listing of all such groups, together with their connective relationships to each other, including the bond types. Several screens are employed to eliminate in certain cases the topological tracing. In the data making up one screen, all terms are listed that represent combinations of chemical significance found in the structure. These terms are made up of at least two functional groups in the topological section and their definitions



Diagrams of question and document compounds. The heavy lines show the specific question and the document embodiments that match. The numbers, arbitrarily assigned, provide a means of indicating the connectivity among the functional groups, as separated by the dotted lines. Each group of alternatives (Markush group) is shown by a bracket. In connection with the generic concept, note that "halogen 41" in the question is answered by "fluorine 22" and that "alkyl, 1–4 61" is answered by "butyl 90".

are fixed and constant. In another screen, generic concepts found in the structure are listed and, where required, defined in terms of the specific functional groups pertinent to the structures under consideration. By referring to these two listings, the program bypasses many unrewarding searches.

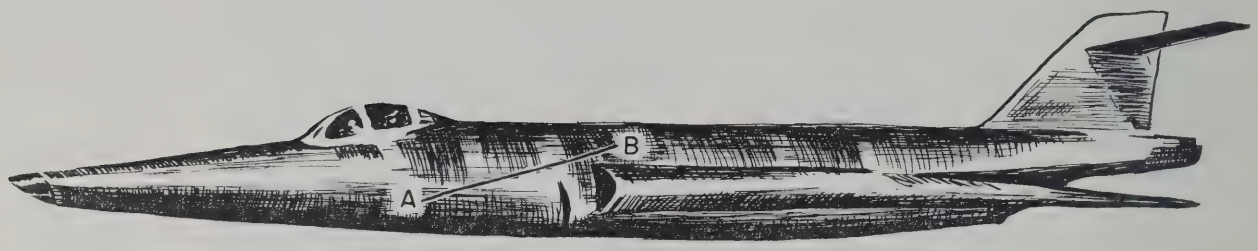
In the topological tracing, as like groups are found, or matched, a table of equivalences is set up of the question groups and of the matching groups actually answering the question. Normally, merely the document number is given by the program as a reference, but in certain complex cases, this "Equivalence Table," which lists all successful matches, can be printed out in its entirety. As it is possible to follow a false trail for a short distance, the program provides for backing up and looking for a rematch.

Recent Work

The most recent work in the HAYSTAQ system has been concerned with the programing of an automatic data-assembly and data-checking routine for the topological tracing program, and the compilation of a large experimental test file. By trying a variety of test questions against the file, it will be possible to gather some meaningful statistics pointing toward the most profitable directions for future research in information retrieval.

For further technical information, see The HAYSTAQ system: past, present and future, *by H. R. Koller, E. Marden, and H. Pfeffer. Preprints of papers for the International Conference on Scientific Information, Washington, D.C. (Nov. 16–21, 1958)*; Organization of chemical disclosures for mechanized retrieval, *Patent Office Research and Development Report No. 5, U.S. Patent Office, Washington 25, D.C.*

Recommendations for a Flight-Load Data-Processing Center



THE National Bureau of Standards, under the sponsorship of the Navy Bureau of Aeronautics, has been studying the computing procedures and equipment needed to process aircraft flight-load data. Recommendations—made to a joint committee of the Air Force, Navy, and National Aeronautics and Space Administration—suggest several optional systems requiring both analog and digital techniques, and include estimates of the processing rates that can be achieved with each. These recommendations are expected to help the committee establish the needs for a computing facility for this operation. This program has been carried out by J. H. Wright, E. S. Sherrard, and D. C. Friedman of the data processing laboratory, as part of the Bureau's service to Government as a central agency for providing information on data-processing applications.

For modern aircraft, the need for adequate design criteria based on actual experience has become increasingly acute with the accelerated demands for higher performance. Statistics, not now available, are required for the entire spectrum of loads encountered by the numerous types of aircraft in regular service, ranging from extreme loads, occurring infrequently, to lesser loads which may occur frequently enough to cause serious structural fatigue after a few hundred or a few thousand hours. The military services are particularly concerned with determining the group of operating conditions defining a mission for a given type of aircraft.

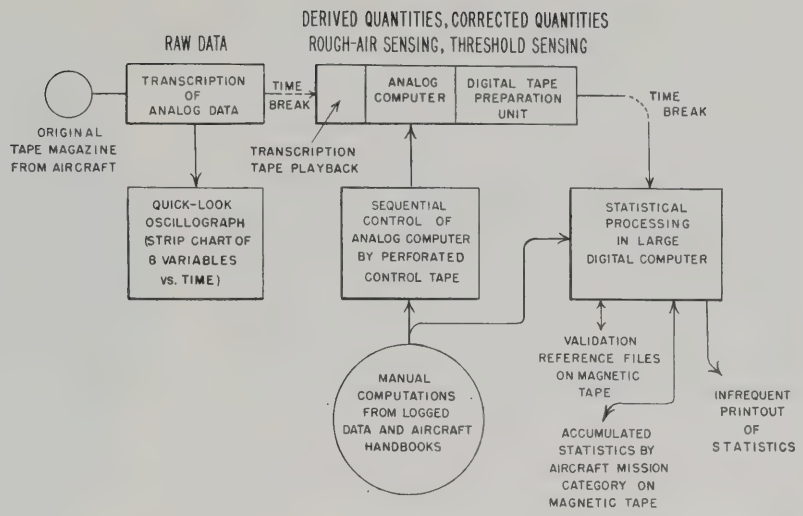
The basic approach, already established by the NASA, requires that airborne recorders develop continuous data on at least eight parameters during flight. These are impact and static air pressures, the three accelerations along, and three angular velocities about, the three body axes of the aircraft. From these data can be derived the various parameters necessary for calculating the component loads on major portions of the aircraft structure, such as the horizontal tail assembly. Probability curves for these parameters can be obtained from their time distributions and other statistics resulting from processing the flight data. These statistics are expected to be used in considering the safe service life of present aircraft, and the probability curves should be helpful in designing aircraft of the same class intended to fly similar missions. The plan is based on the expectation of processing at least 30,000 flight-hours of data annually.

Above: **During flight, system will accumulate data on impact and static air pressures, and the three accelerations along, and the three angular velocities about, the three body axes of the aircraft. Locations of recording device (A) and sensing devices (B) on an aircraft are shown.**

The Air Force and Navy now compute such statistics from visual oscillographic records that nearly always comprise only the normal acceleration component and the classification of aircraft speed and altitude. A special-purpose computing facility, automatically processing flight data that have been recorded directly on magnetic tape, would provide not only an enormous increase in the flight-hours per year that can be processed, but would also deal with enough parameters to provide more realistic criteria for design of aircraft and components.

The Bureau has recommended that processing at the facility under consideration include preliminary editing, correction of measured accelerations to refer them to the center-of-gravity of the aircraft, and derivation of additional parameters such as Mach number, pressure altitude, helix angle, angular accelerations, and products of velocities. Descriptive statistics would be required for 19 quantities both as envelopes of extreme values and in the form of histograms of: (a) Distributions of peaks (recognized by certain logical criteria) classified for correlation with values of other paramaters; (b) simple time distributions; (c) time-of-dwell distributions, classified for correlation. Accumulated statistics should be kept separated for each aircraft and mission category, with further separation of data taken during rough air conditions. A set of about 14,000 tallies will result for each flight processed.

In one of several recommended system configurations, an analog computer is used for preliminary processing, since data inputs from the airborne recorder consist of continuous functions of time. A digital tape


DERIVED QUANTITIES, CORRECTED QUANTITIES
ROUGH-AIR SENSING, THRESHOLD SENSING
RAW DATA
TRANSCRIPTION OF ANALOG DATA
TIME BREAK
ANALOG COMPUTER
DIGITAL TAPE PREPARATION UNIT
TIME BREAK
ORIGINAL TAPE MAGAZINE FROM AIRCRAFT
TRANSCRIPTION TAPE PLAYBACK
QUICK-LOOK OSCILLOGRAPH (STRIP CHART OF 6 VARIABLES VS. TIME)
SEQUENTIAL CONTROL OF ANALOG COMPUTER BY PERFORATED CONTROL TAPE
STATISTICAL PROCESSING IN LARGE DIGITAL COMPUTER
VALIDATION REFERENCE FILES ON MAGNETIC TAPE
MANUAL COMPUTATIONS FROM LOGGED DATA AND AIRCRAFT HANDBOOKS
INFREQUENT PRINTOUT OF STATISTICS
ACCUMULATED STATISTICS BY AIRCRAFT MISSION CATEGORY ON MAGNETIC TAPE

Block diagram illustrating one of the procedures recommended for analyzing aircraft flight-load data. This system uses both analog and digital techniques. It is designed to process 30,000 flight-hours of data expected annually and to obtain statistics in several hundred categories, according to aircraft type and mission.

having a suitable format is prepared during this steady process. The statistical phase of processing is subsequently performed on a conventional digital computer at a processing rate that varies with the character of the flight data.

Although programing studies have shown that the entire task could be carried out on a digital computer, about half the task can be performed more economically on a relatively inexpensive analog computer, although there are some slight attendant complications. In either case, a modern digital computer of the highest speed class is required. Consideration has been given to development of specialized computing units specifically for this application, but preference was given to general-purpose equipment where possible, in the interests of adaptability and straightforward procurement.

For further technical information, see Data processing for the USAF–USN–NASA statistical loads program, *by J. H. Wright, Proc. Air Force Symposium on Fatigue of Aircraft Structures, 11–12–13 August 1959.*

Recent Papers on Data Processing by NBS Authors

Digital recording of electrocardiographic data for analysis by a digital computer, by L. Taback, E. Marden, H. L. Mason, and H. V. Pipberger; Transactions of the Prof. Group on Medical Electronics, IRE (Sept. 1959).

Preparation by electrocardiographic data for analysis by digital electronic computer, by H. V. Pipberger, E. D. Freis, and L. Taback; Circulation (Dec. 1959).

Contour tracing with an analog computer, H. K. Skramstad; Conference Paper 59–461—AIEE General Meeting, Feb. 1–6, 1959.

Data processing for the USAF–USN–NASA statistical loads program, by J. H. Wright; Proceedings of the USAF Symposium on Fatigue of Aircraft Structures, Aug. 11–13, 1959.

A new method of checking consistency of precedence matrices, by Rosalind B. Marimont, Journal of the Assoc. for Computing Machinery (Apr. 1959).

Input-output: key or bottleneck? by R. D. Elbourn, Proc. Computer Applications Symposium, Oct. 1958, Armour Res. Foundation, Chicago, Ill.

NBS multi-computer system, by A. L. Leiner, W. A. Notz, J. L. Smith, and A. Weinberger, Proc. EJCC (Dec. 1958).

Concurrently operating computer systems, by A. L. Leiner, W. A. Notz, J. L. Smith, and R. B. Marimont, Proc. International Conference on Information Processing, Paris, France (June 1959).

Logical plan of the PILOT, by A. L. Leiner, W. A. Notz, J. L. Smith, and A. Weinberger, Journal of Assoc. for Computing Machinery (July 1959).

A machine model of recall, by M. E. Stevens, Proc. International Conference on Information Processing, Paris, France (June 1959).

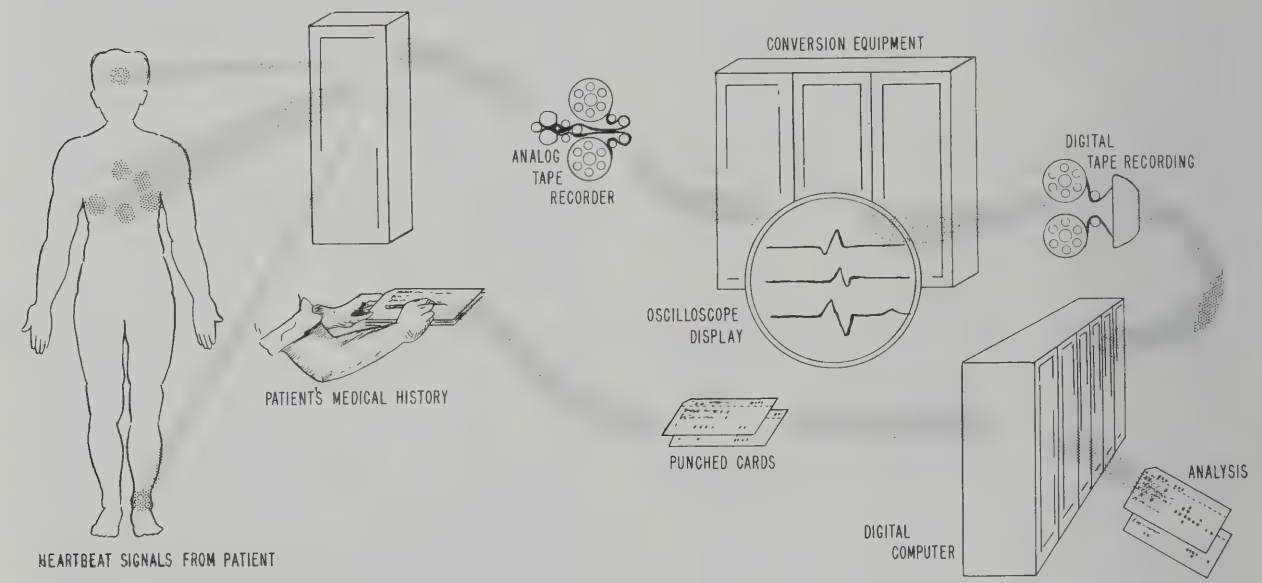
Haystaq system, past, present, and future, by H. R. Koller, E. Marden, and H. Pfeffer, International Conference on Scientific Information (Nov. 1958, reprints).

Analog-digital simulator for design and improvement of man-machine systems, H. K. Skramstad, A. A. Ernst, and J. P. Nigro, Proc. Eastern Joint Computer Conference (1957).

High-Speed Computer to Analyze Human Heartbeat

THE Bureau has developed a method for using computers to compare and analyze heartbeat information, in work sponsored by the Veterans' Administration. Making use of magnetic tape to record heartbeat data and a high-speed digital computer to compare these records, the method can help a physician in making an objective diagnosis of a patient, and it represents an important step toward using a computer to study heart diseases. The method [1] was developed by L. Taback, Ethel Marden, and Dr. H. L. Mason of the Bureau's data processing systems laboratory with the cooperation of Dr. H. V. Pipberger of Veterans' Administration Hospital, Washington, D.C.

The prototype equipment designed and assembled at the Bureau performs what is essentially a conversion process. In this process, heartbeat data recorded on magnetic tape as continuous waveforms (electrocardiograms) are changed to numerical (digital) form, and the resulting numbers are recorded on another magnetic tape in a form acceptable to the computer. These numbers represent the electrical signals associated with the heartbeat. In a computer these numbers can be quickly compared with a normal record for diagnostic purposes, or with various factors among groups of patients for statistical purposes.



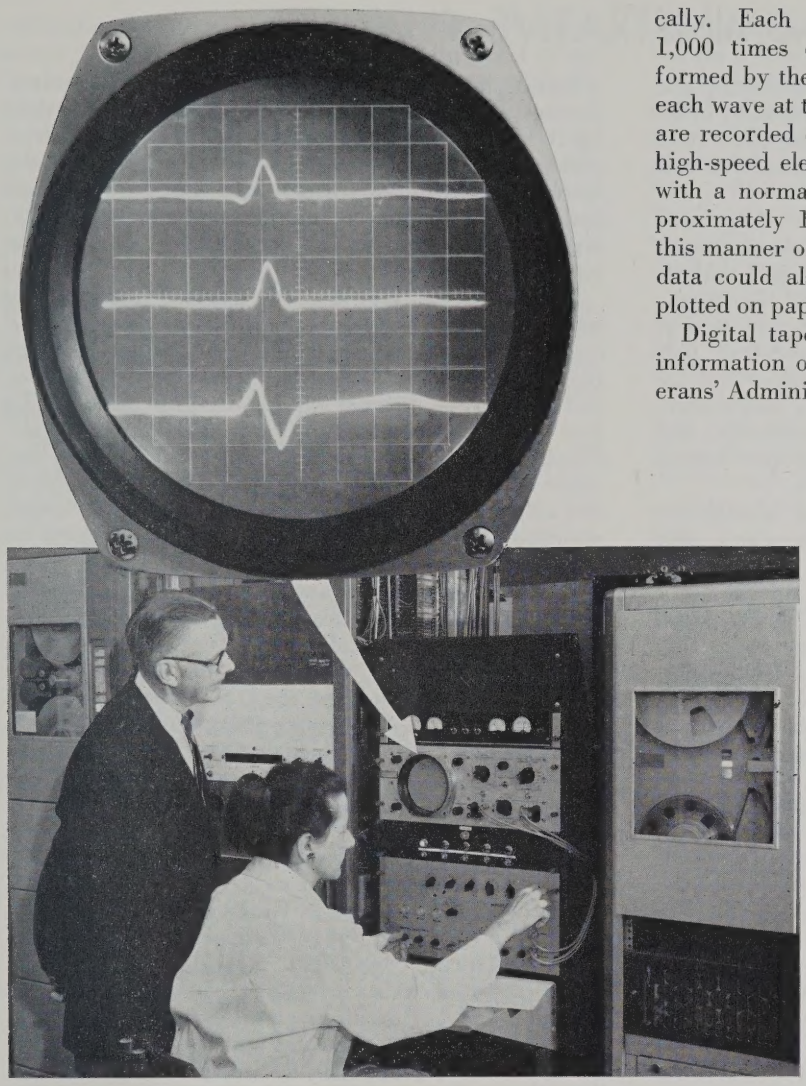
Flow of information for converting heartbeat signals for analysis in a digital computer.

Although much work has been done on the relationship between heart diseases and electrocardiograms, diagnostic methods remain largely empirical. Thus it is desirable to analyze a greater number and variety of heartbeat records so that more accurate limits can be set for normality. The present work shows that adequate statistical studies are feasible when use is made of magnetic tapes and high-speed computers. These tapes have the advantage of being able to store large amounts of data, and they can be used quickly and efficiently to retrieve old records in a form suitable for comparison.

Conversion of Data

As recorded from a patient for this VA research program, an electrocardiogram is a series of 3 continuous waveforms, substantially repetitive with each heartbeat. These waveforms approximate the 3 mutually perpendicular components of the heart vector, as obtained from electrodes placed on the head, chest, and ankle of the patient. They are not suitable for use in a digital computer until they have been changed from analog (continuous-wave) to digital form.

When ready for conversion, the analog tape record-



Left: **Analog-digital converter developed for changing heartbeat data to a form suitable for use in a high-speed computer. Mrs. H. A. Pipberger, medical technician from Georgetown Hospital, selects a suitable cardiac complex by monitoring signals on oscilloscope, as Dr. H. L. Mason of the Bureau looks on.**

Above: **Typical heartbeat waveforms, as seen on the oscilloscope.**

cally. Each of the 3 analog waveforms is sampled 1,000 times each second, and a binary number is formed by the converter to represent the magnitude of each wave at the time of sampling. These magnitudes are recorded on digital magnetic tape, to be used in a high-speed electronic computer either for comparison with a normal record or for cross-correlations. Approximately 1,000 cardiac cycles can be recorded in this manner on one reel of digital magnetic tape. The data could also be printed out on punched cards or plotted on paper charts.

Digital tape records have been made of heartbeat information of several hundred patients, and the Veterans' Administration plans to record additional information concerning these patients on punched cards so that statistical correlations can be made. Data from VA hospitals will be processed in a central installation at Mount Alto Hospital, Washington, D.C.

ing contains 10 or 12 heartbeats on 3 FM channels, and the patient's identification on 1 voice channel. The VA chose wide-deviation FM for recording the heartbeat signals because the frequencies to be studied fall between direct current and 200 cps. A medical technician monitors the 3 signals displayed simultaneously on an oscilloscope and selects a cardiac cycle for conversion to digital form. The display is independent of the heart rate and need not be readjusted for each patient. If desired, the operator can reverse the tape and replay the record. Normally only 1 cardiac cycle is converted for analysis. When heartbeats appear erratic, however, the technician may record more than 1 cycle. By means of a manual selector and a "record" button, the digital record is made in only a few seconds.

In the conversion process, data are sampled periodi-

With additional experience in digital transformation, this digital recording system may be expanded to include other clinical data such as phonocardiograms and hemodynamic pressures and flows. The use of high-speed computers for both diagnosis and statistical analysis of these data should prove a powerful tool for the study of heart diseases.

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[1] *For further information, see* Digital recording of electrocardiographic data for analysis by a digital computer, *by L. Taback, E. Marden, H. L. Mason, and H. V. Pipberger, Trans. IRE,* Professional group on medical electronics (*Sept. 1959*).

RECENT ADMINISTRATIVE CHANGES

Dr. Francis B. Silsbee, Chief of the Electricity and Electronics Division, and Dr. Irvine C. Gardner, Chief of the Optics and Metrology Division, retired in July. Together, they represented over 85 years of service with the Bureau.

Dr. Silsbee joined the Bureau in 1911. Appointed division chief in 1946, he directed the work of laboratories responsible for the establishment and maintenance of the basic electrical units; for testing the standard electrical apparatus and instruments used in science and industry; for the development of new methods for measuring electrical quantities; for the determination of the electrical, magnetic, and electrochemical properties of a wide range of materials; and for the development and testing of electronic devices and components.

From 1947 to 1950 he also supervised laboratories dealing with optical instruments, photometers, and photography.

During World War I, Dr. Silsbee was a leader of a group which conducted development of spark plugs, magnetos, and other components of aircraft ignition systems. He also suggested a theoretical relationship between the values of critical currents and critical magnetic fields in the phenomenon of superconductivity at very low temperatures. This relation has come to be known as the "Silsbee Hypothesis."

During World War II, Dr. Silsbee directed research to mitigate the lightning hazard to nonmetallic aircraft and was later in charge of the development of a special bomb director. He has served as a consultant with the National Advisory Committee on Aeronautics, the National Defense Research Committee, and the Office of the Chief of Ordnance, and has worked extensively with the Committee on Electric and Magnetic Magnitudes and Units of the International Electrotechnical Commission.

In 1956, Dr. Silsbee was sent to Ethiopia by the International Cooperation Administration to advise the Ethiopian Government on the establishment of a national system of measurement standards.

Dr. Gardner joined the Ordnance Department of the Army in 1918. He transferred to the National Bureau of Standards in 1922 to become Chief of the Optical Instruments Section, and was appointed division chief in 1950.

During his early years with the Bureau, Dr. Gardner directed such projects as providing the scientific data for the first Government specification controlling aerial photography for mapping purposes, introducing the special tests required for airplane cameras and their lenses, and developing special testing equipment which served as a model for the equipment used by other national laboratories.

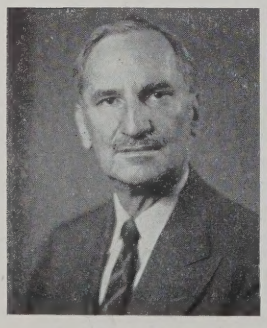
During World War II, Dr. Gardner directed the establishment of a special laboratory in which all field conditions could be simulated while testing military rangefinders under controlled laboratory conditions, and recently, he directed two important projects. The first was the development of an optical method of calibrating to the nearest ten-millionth of an inch, the end gages used by industry. The second was the design of new methods and equipment needed to calibrate length standards by direct comparison with a wavelength of light.

In other personnel changes, Bruce L. Wilson, formerly Chief of the Engineering Mechanics Section, was appointed Chief of the Mechanics Division, succeeding Dr. Walter Ramberg, who joined the Department of State as Science Officer with the U.S. Embassy in Rome.

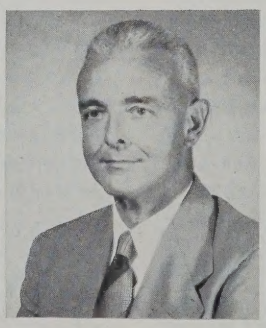
Mr. Wilson will direct a program involving mechanical standards of sound intensity, shock and vibration, pressure, force, mass, and rate of gas and liquid flow; the determination of the density of solids and liquids, the velocity of sound in gases, liquids and solids, and the constant of gravitational force; and studies of the properties of materials and structures.

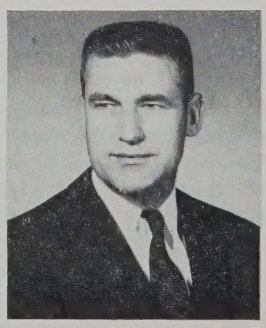
Mr. Wilson was born in Graham, Wash., in 1908, and joined the Bureau after his graduation from Reed College (Oregon) in 1929. During the following years, he worked on problems connected with the accuracy and performance of mechanical testing machines and apparatus, and he was instrumental in the development of calibrating devices for use with large-capacity testing machines. At present he is supervising the design of a 1-million-pound-capacity dead-weight machine for calibrating, with a high degree of accuracy, force-measuring devices such as those used in measuring the thrust of missile engines.

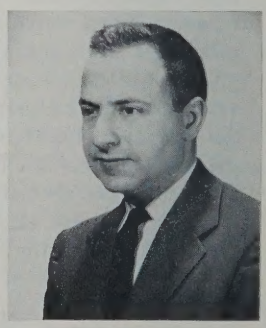
In 1948, Mr. Wilson was appointed Chief of the Engineering Mechanics Section, where he supervised work on engineering and aircraft structures, and the


F. B. Silsbee

I.C. Gardner


B.L. Wilson


L.K. Irwin


A.M. Bass

calibration of force and vibration measuring instruments. In 1957, he was named Assistant Chief of the Mechanics Division. He held both posts until his present appointment.

Succeeding Mr. Wilson, Lafayette K. Irwin was appointed Chief of the Engineering Mechanics Section. He will direct research in the mechanical behavior of engineering structures under load-bearing conditions. He will also lead research on special apparatus and methods for measuring forces, deformations, and hardness, and methods for calibrating such equipment.

Born in Finley, Tenn., in 1922, Mr. Irwin received his B.S. in mechanical engineering from the University of Alabama in 1949. He joined the Engineering Mechanics Section in the same year.

Mr. Irwin was corecipient of the Templin Award of the American Society for Testing Materials in 1957.

Another new section chief, Dr. Arnold M. Bass, was appointed to head the Free Radicals Research Section. He succeeds Dr. Herbert P. Broida, who left in September for a year at Cambridge University.

Dr. Bass has been Assistant Chief of the Free Radicals Section since it was established in 1956 as part of a broad program of research in the field of free radicals undertaken at the request of the Department of Defense. One technique developed in this program is the trapping and storing of these highly reactive molecular fragments at very low temperatures in order to study their physical and chemical properties.

Born in New York in 1922, Dr. Bass received his B.S. from City College of New York in 1942, and his M.A. and Ph. D. from Duke University in 1943 and 1949, respectively. During 1944–46, he served as a radar officer in the U.S. Navy. After a year and a half with the Laboratory for Insulation Research at Massachusetts Institute of Technology, Dr. Bass joined the Bureau's staff in 1950. In 1954, he was appointed Assistant Chief of the Temperature Measurements Section.

New Prefixes for Units

THE National Bureau of Standards has decided to follow the recommendations of the International Committee on Weights and Measures to use new prefixes for denoting multiples and submultiples of units. The Committee adopted the prefixes at its meeting in Paris in the fall of 1958.

In addition to the 8 numerical prefixes in common use, the Committee expanded the following list by adding the 4 prefixes marked with an asterisk. Thus, for example, 10^{-12} farad is called 1 picofarad, and is abbreviated 1 pf.

Multiples and Submultiples	*Prefixes*	*Symbols*
$1\ 000\ 000\ 000\ 000 = 10^{12}$	tera*	T
$1\ 000\ 000\ 000 = 10^{9}$	giga*	G
$1\ 000\ 000 = 10^{6}$	mega	M
$1\ 000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto	h
$10 = 10$	deka	dk
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000\ 001 = 10^{-6}$	micro	μ
$0.000\ 000\ 001 = 10^{-9}$	nano*	n
$0.000\ 000\ 000\ 001 = 10^{-12}$	pico*	p

Publications of the National Bureau of Standards

Periodicals

Journal of Research of the National Bureau of Standards

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Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic $2.25; foreign $2.75.

Section D. Radio Propagation. Issued six times a year. Annual subscription: Domestic $4; foreign $4.75.

Section A. *Physics and Chemistry, Volume* **63A,** *No. 2, September-October 1959. Approx. issue date October 1, 1959.*

Reflection of fast neutrons from water. M. J. Berger and J. W. Cooper.

Some vibrational-rotational bands of deuterated methanes. H. C. Allen, Jr. and E. K. Plyler.

Precise coulometric titration of acids and bases. J. K. Taylor and S. W. Smith.

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A. V. ASTIN, *Director*

October 1959 **Issued Monthly** **Vol. 43, No. 10**

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Contents

	Page
Recent accomplishments in data processing	177
The rapid selector	178
Cloud-height data analyzer	180
A computer routine for logical recall	181
Packaged switching circuits	184
Improved magnetic core digital circuitry	186
Problem solving on the analog computer	188
LENSTAR aids lens design	191
HAYSTAQ—a program for automatic searching of chemical literature	192
Recommendations for a flight-load data-processing center	194
Recent papers on data processing by NBS authors	195
High-speed computer to analyze human heartbeat	196
Recent administrative changes	198
New prefixes for units	199
Publications of the National Bureau of Standards	199

NBS Publications (Continued)

Heat of formation of titanium tetraiodide. W. H. Johnson, A. A. Gilliland, and E. J. Prosen.

Reactions of pentafluorohalobenzenes. W. J. Pummer and L. A. Wall. Tritium-labeled compounds I. Radioassay of tritium-labeled compounds I. Radioassay of tritium-labeled compounds in "Infinitely Thick" films with a windowless, gas-flow, proportional counter. H. S. Isbell, H. L. Frush, and R. Peterson.

Tritium-labeled compounds II. General-purpose apparatus, and procedures for the preparation, analysis, and use of tritium oxide and tritium-labeled lithium borohydride. H. S. Isbell and J. D. Moyer.

Preparation of trichloride and tetrachloride of molybdenum. D. E. Couch and A. Brenner.

Infrared spectra of asphalts. B. D. Beitchman.

Technical News Bulletin, Volume **45**, No. 9, September 1959. 15 cents. Annual subscription $1.50, 75 cents additional for foreign mailing.

Basic Radio Propagation Predictions for November 1959. Three months in advance. CRPL–D180, issued August 1959 and CRPL–D181 issued September 1959. 10 cents. Annual subscription $1; 50 cents additional for foreign mailing.

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Technical Notes

Technical Notes are available only from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. (Order by PB number.)

Calculated behavior of a fast neutron spectrometer based on the total absorption principle, J. E. Leiss. TN10 (PB151369). $1.

Penetration of gamma rays from isotropic sources through aluminum and concrete, M. J. Berger and L. V. Spencer. TN11 (PB151370). 50 cents.

Prediction of the cumulative distribution with time of ground wave and tropospheric wave transmission loss. Part 1. The prediction formula, P. L. Rice, A. G. Longley, and K. A. Norton. TN15 (PB151374). $1.50.

Publications in Other Journals

The role of Government research laboratories, A. V. Astin, Elec. Engr. **78**, No. 7, 738 (1959).

The ampere, F. B. Silsbee, Proc. IRE **47**, No. 5, 643 (1959).

On the theory of reflection from a wire grid parallel to an interface between homogeneous media (II), J. R. Wait, Appl. Sci. Research **7**, 355 (1959).

The basis of our measuring system, A. G. McNish, Proc. IRE **47**, No. 5, 636 (1959).

Reflectors for a microwave Fabry-Perot interferometer, W. Culshaw. IRE Trans. on Microwave Theory and Techniques, Vol. **MTT–7**, No. 2, 221 (1959).

The research frontier, I. C. Schoonover, Saturday Rev. p. 58 (May 2, 1959).

The nature, cause and effect of the porosity in electrodeposits, III. Microscopic detection of porosity, F. Ogburn and D. W. Ernst, Plating **46**, 831 (1959).

Paper test data from pendulum and inertialess testers, R. J. Capott, S. B. Newman, and J. Mandel, TAPPI **42**, No. 6, 480 (1959).

Convexity of the field of a linear transformation, A. J. Goldman and M. Marcus. Can. Math. Bull. **2**, No. 1, 15 (1959).

Factors affecting the accuracy of distortion measurements made on the nodal slide optical bench, F. E. Washer and W. R. Darling, J. Opt. Soc. Am. **49**, No. 6, 517 (1959).

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